

Background Concentrations of Metals in Soils from Selected Regions in the State of Washington

By Kenneth C. Ames and Edmund A. Prych

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
acre	0.4047	hectare
square mile (mi ²)	2.590	square kilometer

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Background Concentrations of Metals in Soils from Selected Regions in the State of Washington

By Kenneth C. Ames and Edmund A. Prych

ABSTRACT

Soil samples from 60 sites in the State of Washington were collected and analyzed to determine the magnitude and variability of background concentrations of metals in soils of the State. This study, done in cooperation with the Washington State Department of Ecology, was conducted because the data are needed to determine if, and to what degree, soils are contaminated at sites where contamination is suspected and to enable the application of consistent clean-up guidelines that accurately reflect specific soil environments. Samples were collected from the predominant taxonomic soil series in 12 different regions that are representative of large areas of Washington. Individual sites were chosen in areas that were relatively undisturbed by human activities.

Concentrations of metals were determined by five different laboratory methods that used different extraction procedures to recover metals from samples for analysis. Concentrations of 43 metals were determined by a total method that uses strong acids to extract at least 95 percent of each metal from the sample. Concentrations of 16 metals were determined by a total-recoverable method that also uses strong acids but that extracts less of a metal than does the total method. Concentrations of 17 metals were also determined by 3 methods that used distilled water or a weak acid to leach metals that are bound to the soil. These methods are the American Society for Testing and Materials method D3987-85, the Extraction Procedure Toxicity test, and the Toxicity Characteristic Leaching Procedure. Concentrations of metals determined by these methods were typically less than 1 percent of the concentrations

determined by the total method, and concentrations of most metals determined by these methods were less than the laboratory's minimum reporting levels.

The concentrations of metals in uncontaminated soils collected in Washington State varied by as much as 62-fold. However, concentrations of metals determined by the total method generally displayed less variability than values determined by the other laboratory methods. Concentrations of mercury determined by the total method and nickel determined by both the total and total-recoverable methods displayed the greatest variability, followed by chromium and copper determined by the total-recoverable method; all have arithmetic standard deviations greater than two-thirds of their respective arithmetic means. Concentrations of other metals, such as aluminum and barium determined by the total method, varied less; both have arithmetic standard deviations less than one-third of their respective means.

Most metals concentrations determined by either the total or the total-recoverable methods were found to be from log-normally distributed populations or were more nearly log-normally than normally distributed. However, concentrations of four metals determined by the total method and three metals determined by the total-recoverable method were found to have been sampled from populations that were normally distributed.

The Kruskal-Wallis test indicated that metals concentrations determined by either the total or the total-recoverable methods were significantly different among the 12 regions, with the exceptions of total copper and total manganese concentrations. However, the Fisher's

Least Significant Difference test, used to locate differences among the 12 population means for each metal, indicated that total metals concentrations between many regions were not statistically distinct. In contrast, metals concentrations determined by the total-recoverable method were not as similar among different regions, and only total-recoverable concentrations of arsenic and lead were statistically similar (at a 95 percent confidence level) among the different regions. Cluster analysis revealed that sampling sites in three regions encompassing the Puget Sound could be regrouped to form two new regions. One group consists of sites located in an inner ring encompassing Puget Sound, and the other group forms an outer ring in the Puget Sound uplands. Sites in three regions in south-central and southeastern Washington State could also be regrouped into two new regions.

For 7 of 11 metals tested, concentrations of metals determined by the total method correlated with concentrations of metals determined by the total-recoverable method at a 95 percent confidence level. For 6 of 18 metals tested, concentrations of metals determined by the total method also correlated positively with organic carbon concentrations. Concentrations of metals determined by the total-recoverable method did not correlate at a 95 percent confidence level with either organic carbon concentrations or the amounts of fines, suggesting that concentrations of metals determined by this method are primarily dependent upon the partial digestion of the various mineral phases within each sample. Concentrations of most metals determined by the leaching methods did not correlate with concentrations of metals determined by either the total or the total-recoverable methods and did not correlate with the amount of carbon or silt- and clay-sized particles. Therefore, the concentrations of metals in the leachates are probably independent of the exchange capacity in the soils. The analytical method for total concentrations was typically about twice as precise as was the total-recoverable method, and the leaching methods were much less precise than either the total or total-recoverable method.

INTRODUCTION

In 1987 the Washington State Department of Ecology (Ecology) and the U.S. Geological Survey (USGS) began a series of cooperative studies to obtain information on the magnitude and variability of background metals concentrations in soils. This information was needed to determine if, and to what degree, soils were contaminated at sites where contamination is suspected and to enable the application of consistent clean-up guidelines that accurately reflected specific soil environments.

Background

The first of these studies was a pilot investigation of a part of the Big Soos Creek drainage basin in King County. In that study (Prych and others, 1995) 27 soil samples were collected from 9 sites over an area of about 30 mi² at depths up to 5 feet (fig. 1). The samples were analyzed for 17 to 44 different elements by 4 different laboratory methods. The U.S. Environmental Protection Agency's priority pollutants of primary interest included antimony (Sb), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), and zinc (Zn) (U.S. Environmental Protection Agency, 1988). (For convenience, all elements will hereafter be referred to as metals.)

The method used to extract metals from a soil sample in the laboratory can strongly influence the reported concentrations of metals in the soil. Although several different methods are commonly used in environmental investigations, four of the most common methods were used in the Soos Creek study. Two of them were a total and a total-recoverable method. The total method involved complete digestion of the solid material, whereas the total-recoverable method removed less than 95 percent of the solid material (Fishman and Friedman, 1985). Metals concentrations determined by the two methods were found to differ by as much as an order of magnitude. Metal concentrations were also determined from leachates produced by two different methods used to simulate leaching processes in soils under extreme conditions: ASTM (method D3987-85, American Society for Testing and Materials, 1985) and EP-TOX (Extraction Procedure Toxicity Test; method 1310, U.S. Environmental Protection Agency, 1986). Because the distribution of metals in soil and the extractability of metals from soil samples are influenced by such soil characteristics as particle-size distribution, pH, and content of organic matter, the Soos Creek study determined these characteristics for each of the samples collected.

The Big Soos Creek drainage basin study provided both a foundation of information and a model from which future study designs could be formulated. However, the knowledge about background metals concentrations in soils was limited by the relatively small study area and small number of samples, and the transferability of the results of the Soos Creek study to areas outside of its drainage basin was unknown. This present study was designed to cover a much larger area of the State so that the distribution and variability of metals in soils in

representative regions in the State could be assessed and the qualitative and quantitative differences between these regions could be compared.

Purpose and Scope

This report presents data on the magnitude and variability of background concentrations of metals in soils in selected regions throughout the State of Washington and the determinations of differences among selected regions. The report presents, in tabular form, all the data collected for this study and summary statistics for all metals determined by the five laboratory methods. The frequency distributions of the data are discussed, and analyses of the variability of concentrations of metals determined by the total and total-recoverable methods among regions are presented, as are the matrices of correlation coefficients between total and total-recoverable metals concentrations and between metals concentrations and other soil characteristics.

Acknowledgments

Appreciation is expressed to Ward Staubitz and Laura Forsman for their extraordinary contributions to this report and to Charles San Juan of the Washington State Department of Ecology, whose cooperation was essential to the study.

STUDY AREA AND SOIL REGIONS

Samples were collected from regions A, C, D, F, G, J, L, M, O, P, R, and U (fig. 2). Even though a region contains a number of different soil series, the number of soil series sampled within a single region depended on the original sampling design. Certain regions were chosen to have multiple samples retrieved from a single soil series at different locations, while other regions had samples collected from five different soil series. Table 1 lists the locations and physical descriptions of the soils sampled from every region, and the Description of Soils section lists the characteristics of soils common within a region and of the series sampled for each region.

Sampling Design

A stratified sampling design, described by Bennett and Franklin (1954) and Iman and Conover (1983), was used to incorporate the areal differences among soils in Washington State. The State was divided into 24 different regions (fig. 2), which were adapted from the general soil groups of Washington (Chapin, 1968), the physiographic regions presented by Livingston (1969) and Lasmanis (1991), and the major geologic units that compose the State (Hunting and others, 1961). Twelve of these regions, which compose the majority of land most affected by urban, agricultural, and industrial development, were sampled in this study. Samples were collected from the predominant taxonomic soil series in each region. In most regions, soils from three or more different soil series were collected; however, in some regions, one or two soil series were so extensive that samples were collected only from those series. Soil samples were collected at 5 sites in each region (for a total of 60 samples). The locations of individual collection sites within a specified soil series were chosen at random in areas that were relatively undisturbed by man (that is, away from major roads or highways, housing developments, farming or cultivated areas, and so on).

For this report, the term sampling site, or site, refers specifically to an area of approximately 1 acre, from which a composite was made from five samples collected at shallow depth (less than 38 inches) and thoroughly mixed to produce one representative sample to reduce the effect of local variability. Samples are designated by region and site (for example, sample A2 denotes a sample collected in region A at site 2). Duplicate samples are always designated as site location 6, and a duplicate designation immediately follows the designation of the sample from which a duplicate was made. For example, sample F6 is the duplicate of sample F2 (see table 1).

Five samples from each of the 12 regions were collected and analyzed for 16 metals by the total-recoverable method, for PCB's, for TPH, and for particle-size distribution. Three samples from each region were analyzed for 43 metals by the total method and for organic and inorganic carbon. One sample from each region was analyzed for 17 metals by the ASTM, EP-TOX, and TCLP methods. Table 2 lists the individual metals determined by each laboratory method and their respective laboratory minimum reporting levels. Explanations of each of the different analytical methods are presented in the "Laboratory Methods" section.

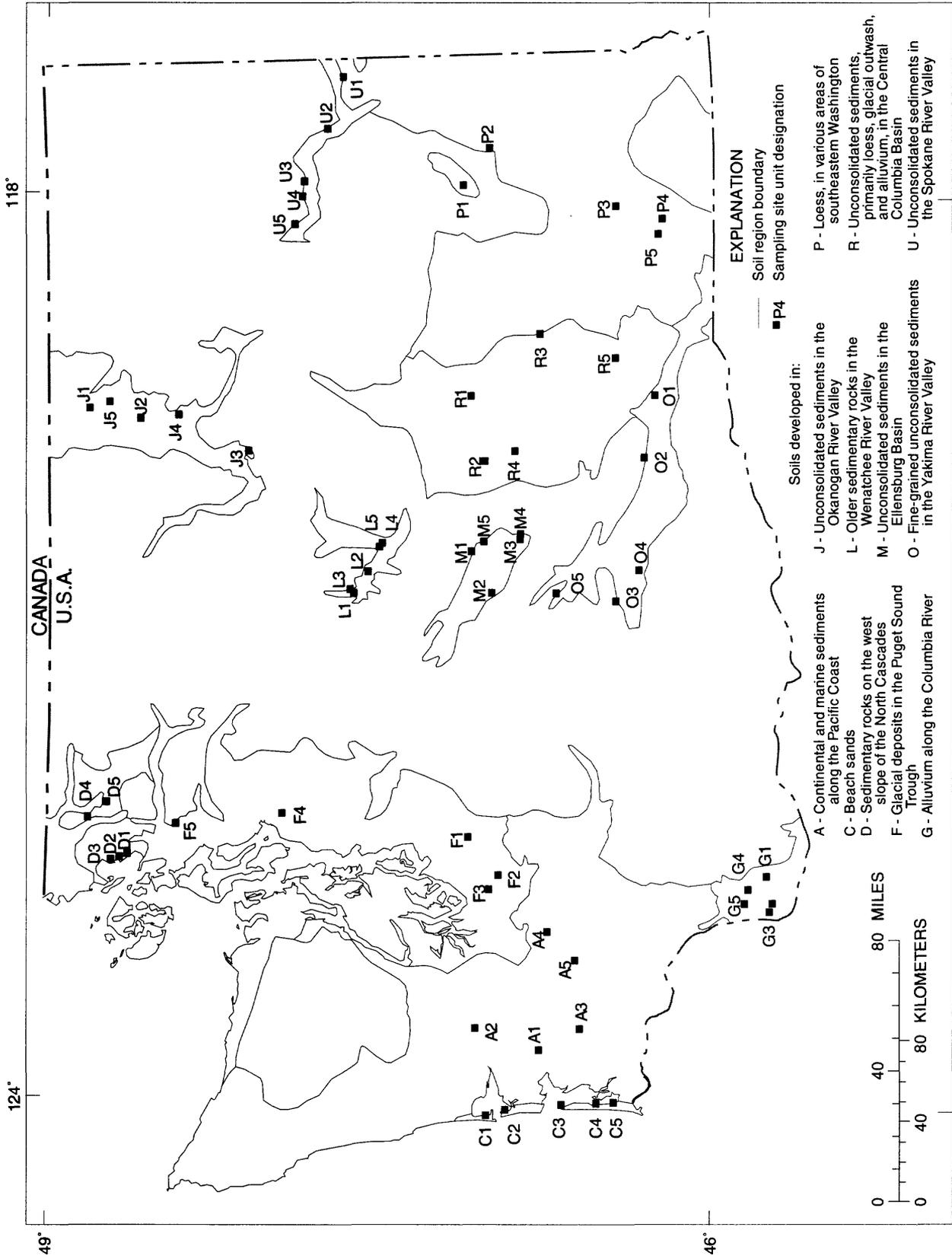


Figure 2.--Location of sampled sites in selected soil regions of Washington State (adapted from Ames, 1994).

Table 1.--Sampling locations and physical descriptions of soils in Washington

[Soil description abbreviations of colors and qualifiers: brn, brown; ol, olive; lt, light; dk, dark; pl, pale; yl (preceding color), yellowish; brn (preceding color), brownish; gry (preceding color), grayish; ext, extremely; grv, gravelly; fn, fine]

Sample number	Latitude	Longitude	Land surface elevation (feet)	Soil series ¹	Soil description ²	Soil horizon ³	Sample depth (inches)	
							top	bottom
Soil samples from Region A:								
A1	46 39 37	123 45 36	280	Willapa	yl. brn. silty clay loam	B2	24	30
A2	46 59 52	123 35 42	160	Zenker	dk. brn. loam	B2	24	30
A3	46 31 10	123 33 52	360	Zenker	dk. brn. loam	B2	24	30
A4	46 41 20	122 55 27	480	Melbourne	dk. brn. silty clay	B21	24	27
A5	46 33 37	123 06 23	520	Melbourne	dk. brn. silty clay	B21	24	27
A6	(duplicate of sample A5)							
Soil samples from Region C:								
C1	46 55 53	124 09 57	10	Dune land	gray sand	--	26	30
C2	46 51 25	124 06 34	2	Dune land	gray sand	--	25	31
C3	46 36 28	124 02 32	20	Netarts	lt. brn. gray fine sand	C	25	31
C4	46 26 02	124 03 17	5	Dune land	gray sand	--	26	30
C5	46 21 16	124 01 57	20	Yaquina	ol. brn. fine sand	C	24	30
Soil samples from Region D:								
D1	48 39 04	122 29 30	340	Cathcart	lt. brn. sandy loam	B2	22	28
D2	48 39 08	122 29 26	70	Cathcart	lt. brn. sandy loam	B2	22	28
D3	48 41 52	122 29 29	250	Cathcart	lt. brn. sandy loam	B2	25	31
D4	48 48 09	122 10 33	310	Schnorbush	lt. brn. clay loam	B3	26	32
D5	48 43 32	122 05 27	1,150	Heisler	brn. clay loam	B2	24	30
Soil samples from Region F:								
F1	47 03 53	122 18 24	540	Everett	brn. sandy loam	C	26	32
F2	46 55 01	122 33 33	380	Spanaway	lt. brn. gray loamy sand	C	24	30
F6	(duplicate of sample F2)							
F3	46 57 28	122 39 04	370	Everett	ol. brn. loamy sand	C	24	30
F4	47 54 51	122 10 40	120	Everett	brn. sandy loam	C	24	30
F5	48 24 13	122 10 25	800	Everett	brn. sandy clay loam	C	26	32

Table 1.--Sampling locations and physical descriptions of soils in Washington--Continued

Sam- ple num- ber	Lat- itude	Long- itude	Land surface elevation (feet)	Soil series ¹	Soil description ²	Soil horizon ³	Sample depth (inches)	
							top	bottom
Soil samples from Region G:								
G1	45 41 59	122 30 43	267	Lauren	brn. loam	B2	24	30
G2	45 40 14	122 40 57	50	Wind River	dk. gry. brn. loamy sand	C1	24	30
G3	45 40 50	122 44 24	10	Sauvie	dk. gr. brn. clay loam	B2	24	30
G4	45 46 53	122 35 58	215	Dollar	brn. loam	B2	24	30
G5	45 47 42	122 41 35	175	Gee	dk. brn. silty clay loam	B	24	30
Soil samples from Region J:								
J1	48 48 33	119 24 16	255	Colville	lt. gray silty clay loam	B2	26	32
J2	48 34 46	119 28 36	950	Pouge	brn. sandy loam	IIC	30	36
J3	48 05 22	119 41 53	770	Pouge	brn. sandy loam	IIC	28	34
J4	48 24 15	119 27 05	1,200	Pouge	brn. sandy loam	IIC	32	38
J5	48 43 13	119 21 53	1,480	Cashmere	pl. brn. sandy loam	C1	30	36
Soil samples from Region L:								
L1	47 36 42	120 40 21	1,600	Burch	yl. brn. sandy loam	C1	26	32
L2	47 32 51	120 31 28	1,200	Burch	yl. brn. sandy loam	C1	26	32
L3	47 37 40	120 38 24	1,500	Burch	yl. brn. sandy loam	C1	26	32
L4	47 29 24	120 20 00	1,250	Burch	yl. brn. sandy loam	C1	26	32
L6	(duplicate of sample L4)							
L5	47 29 43	120 21 17	1,280	Burch	yl. brn. sandy loam	C1	25	31
Soil samples from Region M:								
M1	47 04 33	120 22 47	2,320	Wenas	dk. gry. brn. sandy loam	B2	24	30
M2	46 58 46	120 39 19	1,900	Naches	dk. yl. brn. clay loam	B3	25	31
M3	46 51 14	120 17 24	2,140	Renslow	brn. loam	B2t	25	31
M4	46 51 2	120 16 24	2,215	Selah	lt. brn. gray clay	B22	25	31
M5	47 00 58	120 38 55	1,760	Reeser	brn. silt loam	B2	24	27
Soil samples from Region O:								
O1	46 14 32	119 19 54	1,300	Shano	pl. brn. silt loam	B3	24	30
O2	46 17 27	119 44 35	1,180	Warden	pl. brn. silt loam	B2	24	30
O3	46 25 22	120 45 26	1,120	Shano	pl. brn. silt loam	B3	24	30
O4	46 18 43	120 29 37	1,000	Warden	pl. brn. silt loam	B2	24	27
O5	46 41 14	120 39 16	1,335	Weirman	gry. brn. ext. grv. sand	IIC2	20	26

Table 1.--Sampling locations and physical descriptions of soils in Washington--Continued

Sam- ple num ber	Lat- itude	Long- itude	Land surface elevation (feet)	Soil series ¹	Soil description ²	Soil horizon ³	Sample depth (inches)	
							top	bottom
Soil samples from Region P:								
P1	47 06 08	117 54 45	1,710	Walla Walla	dk. brn. silt loam	B3	28	34
P2	46 58 48	117 43 02	470	Athena	brn. silt loam	B22	30	36
P3	46 24 37	118 04 14	1,680	Athena	brn. silt loam	B22	30	36
P6	(duplicate of sample P3)							
P4	46 11 53	118 09 28	1,770	Athena	brn. silt loam	B22	30	36
P5	46 13 07	118 15 28	1,230	Walla Walla	dk. brn. silt loam	B3	32	38
Soil samples from Region R:								
R1	47 04 46	119 19 53	1,060	Quincy	brn. fn. sand	C2	24	30
R2	47 00 53	119 46 11	1,150	Quincy	brn. fn. sand	C2	24	32
R3	46 45 54	118 49 44	1,000	Shano	pl. brn. silt loam	C1	24	30
R4	46 52 50	119 42 16	1,110	Taunton	pl. brn. silt loam	B2	24	30
R6	(duplicate of sample R4)							
R5	46 25 24	119 04 52	900	Taunton	pl. brn. silt loam	B2	24	27
Soil samples from Region U:								
U1	47 37 43	117 10 00	2,220	Marble	dk. brn. loamy sand	C1	22	28
U2	47 43 13	117 30 53	1,710	Springdale	lt. brn. sand	C3	24	30
U3	47 50 37	117 51 47	1,430	Ewall	pl. brn. sand	C2	28	34
U6	(duplicate of sample U3)							
U4	47 50 02	117 58 05	1,300	Spens	brn. loamy sand	C2	25	31
U5	47 52 32	118 09 11	1,480	Ewall	pl. brn. sand	C2	25	31
Reference soil samples:								
RS1	mixture of soils collected within the Soos Creek Basin, Washington							
RS2	(duplicate of sample RS1)							

¹ Soil series names from Soil Conservation Service publications; note that names of soils in regions D and M may change in the future because surveys for Whatcom and Kittitas Counties are being updated.

² U.S. Department of Agriculture (1962) soil textural classes determined; samples were sieved in the field to remove material larger than 19 millimeters; as a result, qualifiers for coarse gravel or cobble, which would otherwise be included, may not be included in the soil description. Note that soils from the following series commonly contain gravel or cobbles at the sampled horizon level: Everett, Spanaway, Lauren, Pouge, Springdale, and Spens.

³ Soil horizons determined in office using sample depth and physical soil characteristics. Horizons are relatively parallel layers of soil that have distinct characteristics which represent departures from the parent material. Typically the A horizon overlies the B horizon, together composing the solum. The C horizon overlies the parent material and is beneath the solum. For additional information see U.S. Department of Agriculture (1962).

Table 2.--Reporting levels for metals in soils in Washington analyzed by different methods

[Values in parentheses are given in milligrams per liter of leachate; level of detection may exceed minimum reporting level; --, lack of a reporting level indicates that analysis was not performed; ASTM, American Society for Testing and Materials method D3987-85; EP-TOX, Extraction Procedure Toxicity Test, U.S. Environmental Protection Agency method 1310; TCLP, Toxicity Characteristic Leaching Procedure, U.S. Environmental Protection Agency method 1311]

Metal		Minimum laboratory reporting levels, by analytical method, in milligrams per kilogram of dry soil			
Symbol	Name	Total	Total recoverable	ASTM, EP-TOX, and TCLP	
Ag	Silver	2	0.2	0.04	(0.002)
Al	Aluminum	500	7.0	1.0	(.1)
As	Arsenic	10	.5	.6	(.03)
Au	Gold	8	--	--	--
Ba	Barium	1	--	.1	(.01)
Be	Beryllium	1	.5	.4	(.02)
Bi	Bismuth	10	--	--	--
Ca	Calcium	500	--	--	--
Cd	Cadmium	2	.2	.04	(.002)
Ce	Cerium	4	--	--	--
Co	Cobalt	1	--	--	--
Cr	Chromium	1	1.5	.1	(.01)
Cu	Copper	1	1.0	.4	(.02)
Eu	Europium	2	--	--	--
Fe	Iron	500	2.0	.4	(.02)
Ga	Gallium	4	--	--	--
Ho	Holmium	4	--	--	--
Hg	Mercury	.02	.004	.0008	^a (.00004)
K	Potassium	500	--	--	--
La	Lanthanum	2	--	--	--
Li	Lithium	2	--	--	--
Mg	Magnesium	50	--	--	--
Mn	Manganese	4	1.0	.4	(.02)
Mo	Molybdenum	2	--	--	--
Na	Sodium	50	--	--	--
Nb	Niobium	4	--	--	--
Nd	Neodymium	4	--	--	--
Ni	Nickel	2	7	.4	(.02)
P	Phosphorus	50	--	--	--
Pb	Lead	4	10	.4	(.02)

Table 2.--Reporting levels for metals in soils in Washington analyzed by different methods--Continued

Metal		Minimum laboratory reporting levels, by analytical method, in milligrams per kilogram of dry soil			
Symbol	Name	Total	Total recoverable	ASTM, EP-TOX, and TCLP	
Sb	Antimony	0.1	3.0	0.4	(0.02)
Sc	Scandium	2	--	--	--
Se	Selenium	.1	.5	1.0	(.1)
Sn	Tin	10	--	--	--
Sr	Strontium	2	--	--	--
Ta	Tantalum	40	--	--	--
Th	Thorium	4	--	--	--
Ti	Titanium	50	1.5	--	--
Tl	Thallium	--	5.0	.4	^b (.02)
U	Uranium	100	--	--	--
V	Vanadium	2	--	--	--
Y	Yttrium	2	--	--	--
Yb	Ytterbium	1	--	--	--
Zn	Zinc	4	2.0	.4	(.02)

^a Minimum reporting level for TCLP mercury is 0.001 milligram per kilogram of dry soil or 0.0001 milligram per liter of leachate.

^b Minimum reporting level for TCLP thallium is 2.0 milligrams per kilogram of dry soil or 0.1 milligram per liter of leachate.

Duplicates of samples A5, F2, L4, P3, R4, and U3 were obtained from sample splits. For quality assurance, these duplicates were submitted to the laboratories without the laboratories being informed that the samples were duplicates (so-called blind samples). A reference sample (RS1) constructed during the Soos Creek study from many different sites (Prych and others, 1995) was also submitted to the laboratories. A duplicate of RS1 was also submitted to various laboratories blind with the other duplicates.

Description of Soils

The soils in the State of Washington are diverse. They have developed over different lengths of time, in a great variety of parent materials, upon diverse terrains, with highly contrasting climates. In fact, they range from highly developed soils formed in marine volcanoclastic sediments to soils with little profile development formed in recently deposited glacial sediments. Twelve of the 24 regions were chosen for this study (fig. 2).

Region A

Soils in region A developed mainly in continental and marine sedimentary beds deposited in southwestern Washington (Pringle, 1986), and all soils sampled in this region developed on upland marine sediments. Samples were collected from the Willapa, Zenker, and Melbourne series. Willapa soils developed on marine terraces that were cut into marine sediments and bedrock following changes in sea level (Pringle, 1986). Zenker soils formed in material weathered from sandstones derived from a volcanic range to the east of the present Washington coast. Melbourne soils formed in material weathered from marine deposited siltstone, shale, and fine-grained sandstone.

Region C

All soils in region C formed in beach sands located along the southwestern Washington coast. Three of the five samples were collected from "dune lands," which consist of excessively drained ridges formed in fine beach

sand, and the other two were collected from the Netarts and Yaquina series. Soils from the Netarts series formed in upland areas, and soils from the Yaquina series formed in basin-like areas between sand dunes (Pringle, 1986).

Region D

Soils in region D typically developed in older sedimentary rocks on the northwestern side of the Cascade Range (Poulson, 1953). Samples were collected from the Cathcart, Heisler, and Schnorbrush series. Soils from the Cathcart series formed in sandstones and shales developed from glacially scoured consolidated sandstone. Soils from the Heisler series commonly occur in high mountain valleys west of Mt. Baker and formed in glacial moraines developed from argillite, schist, and shale, which apparently accumulated from alpine and continental glaciations (Poulson, 1953). Schnorbrush soils are confined to the valley of the Nooksack River and were derived from arkosic sandstone and drift material that border the mountain sides. Talus rubble from alpine glaciers may also have contributed to the parent material.

Region F

Most soils in region F formed in glacial deposits in the Puget Sound lowlands of western Washington (Zulauf, 1979). Samples were collected from both the Everett and Spanaway soil series. Soils from the Everett series formed on gravelly glacial outwash located on terraces and terrace breaks. Spanaway soils, which also formed in glacial outwash, commonly contain volcanic ash in the upper solum and are the "most extensive soil on the outwash plain of the last continental, or Vashon, glaciation period" (Ness, 1958, p. 54).

Region G

Soils in region G along the lower Columbia River commonly are derived from alluvium deposited from vastly different sources (McGee, 1972). Soils were collected from the Lauren, Wind River, Sauvie, Dollar, and Gee series. Lauren soils developed on Columbia River terraces 50 to 300 feet above the present level of the river in mixed alluvium that contains some volcanic ash. Wind River soils also developed in Columbia River mixed-alluvium deposits 150 to 500 feet above the present river level. Soils of the Sauvie series formed in alluvial bottom lands along the river. Soils from both the Dollar and Gee

series formed in older Columbia River alluvium. Dollar soils developed on low nearly level terraces, whereas Gee soils are found in rolling hills on eroded terraces.

Region J

Soils in region J commonly developed in unconsolidated deposits in the Okanogan River Valley located in north-central Washington, and samples were collected from the Colville, Pouge, and Cashmere series. Soils from the Colville series formed in mixed alluvium derived from acidic igneous rocks and volcanic ash. Pouge soils developed on terraces and terrace breaks and are underlain by gravelly sandstones deposited as glacial outwash. Cashmere soils also formed in glacial outwash and more recent alluvium (Lenfesty, 1980).

Region L

Region L is located in the northeastern foothills of the Cascade Range. Soils in this region developed primarily on older sedimentary rocks in the Wenatchee River Valley. All samples collected from this region were from the Burch soil series. Burch soils specifically formed on terraces composed of old alluvium derived from sandstone (Beieler, 1972).

Region M

Soils in region M commonly formed in unconsolidated loess and alluvium deposits in the Ellensburg Basin located in central Washington. Samples were collected from the soils of the Renslow, Selah, Naches, Reeser, and Wenas series. Renslow and Selah soils formed in loess; Selah soils may also contain a sub-layer of caliche and are commonly underlain by gravelly old valley fill. Soils in the Naches series also developed in old valley fill. Reeser soils formed over cemented gravels, and soils from the Wenas series developed in stream bottom material composed chiefly of weathered basalt (Smith and others, 1945).

Region O

Region O is located immediately south of the Ellensburg basin. The soils sampled in this region developed in fine-grained sediments deposited in the Yakima River Valley. Soils were collected from the Shano, Warden, and Weirman series. Shano soils formed in loess,

whereas Warden soils formed in a "thin mantle of loess" underlain by glaciolacustrine sediments (commonly referred to as Touchet beds) (Lenfesty and Reedy, 1985; and Rasmussen, 1971). Weirman soils formed in mixed alluvium located in flood plains or low terraces.

Region P

Region P extends throughout much of southeastern Washington, and soils in this area formed in thick deposits of loess (Harrison and others, 1964; Harrison and others, 1973; and Donaldson, 1980). Samples were collected from both the Walla Walla and Athena series. Both the Walla Walla and Athena soils formed in loess interstratified with volcanic ash (Donaldson, 1980), and at some localized depressions, deposits of ash may be from 1 to 6 feet thick. Athena soils, however, are commonly located in higher elevations, whereas Walla Walla soils are commonly found at elevations below 2,000 feet.

Region R

Soil samples collected in this region commonly formed in unconsolidated wind-blown and alluvial sediments in the central Columbia Basin located in southeastern Washington. The Quincy, Shano, and Taunton series were sampled. Quincy soils are located on terraces or active sand dunes and were formed in eolian sands (Gentry, 1984; Lenfesty, 1967; and Van Duyne and others, 1917). Shano soils formed in thick deposits of loess interstratified with volcanic ash. Taunton soils developed in wind-worked alluvium and are commonly underlain by lime- and silica-cemented hardpans at shallow depth (Gentry, 1984).

Region U

All samples in this region were from soils that developed in unconsolidated deposits in the Spokane River Valley located in northeastern Washington. Samples of Marble, Springdale, Ewall, and Spens soils were collected. Marble soils formed on terraces in wind-worked mixed sandy outwash (Donaldson and others, 1982; and Donaldson and Giese, 1968). Springdale soils developed in outwash mantled with volcanic ash and loess (Donaldson and others, 1982; Donaldson and others, 1968; and Stockman, 1981). Ewall and Spens soils also formed in glacial outwash. Ewall soils typically are located on terraces, whereas Spens soils are located on terrace breaks (Stockman, 1981).

METHODS

This chapter presents the procedures used to collect and process soil samples and the individual laboratory methods used to determine metals concentrations and other chemical and physical soil characteristics. The analytical precision of laboratory determinations are presented, and the ranges of precision among the total, total-recoverable, ASTM, EP-TOX, and TCLP methods are discussed.

Sample Collection and Processing

Samples were collected during July, August, and September of 1990. In the earlier Big Soos Creek pilot study, samples collected closer to the surface displayed a greater variability in metals concentrations than those samples collected at greater depths (Prych and others, 1995). For the current study, soil samples were collected from a depth of at least 20 inches below ground surface and were located within either the B or C horizon to (1) decrease variability and (2) minimize contamination from possible surface pollutants. A shovel was used to dig a hole from 12 to 24 inches in diameter by 24 inches deep at the center and at each corner of a 1-acre plot. A stainless-steel soil auger was used to collect 1 to 2 liters of material from approximately a 6-inch layer below the bottom of the hole. The material from each hole was sieved in the field through a 19.0 mm stainless-steel crimped sieve and was placed in a 20-liter plastic bucket. The five samples in the bucket were mixed thoroughly to form one representative composite sample to reduce the effect of areal variability. A subsample (approximately 3 to 4 liters in volume) of the composite sample was placed in a 4-liter plastic container for further sieving and sample splitting in the laboratory. A second subsample, approximately 0.3 liter in volume, was sieved through a 2.0-mm stainless-steel crimped sieve in the field and was placed in a cleaned glass jar and stored on ice for later analysis for PCB's and TPH. After all the soil samples at a site had been collected, all sampling and processing equipment was washed with tap water and detergent (Alconox), then rinsed sequentially with tap water, with a 60/40 acetone/hexane solution, and finally with deionized water.

The primary subsample was further divided into representative sample splits at the USGS field services unit in Tacoma, Wash. The sample splits were produced by flattening, mixing, and quartering the soil as described by the ASTM method D3987-85 (American Society for Testing and Materials, 1985). The sample splits were used as allotments for the various analyses and duplicates.

Sample splits for determining particle-size distribution and soil-solution pH were analyzed without further treatment. Splits that were to be analyzed by the total-recoverable, ASTM, EP-TOX, and TCLP methods were dry sieved to remove particles larger than 2.0 mm (millimeters). All sample splits to be analyzed by the total method were additionally wet sieved using a polypropylene sieve to obtain only material less than 63 μm (micrometers) in size for analyses, because trace metals tend to concentrate in finer sized (silt- and clay-sized) particles (Kabata-Pendias and Pendias, 1984).

Laboratory Methods

Five different laboratory methods were used to determine metal concentrations in the soil samples. Each method produced a liquid extract that was analyzed either by atomic-absorption or by inductively-coupled plasma emission spectrometry. Differences among solvents and extractive processes have the most significant effect on the metal concentrations in the resulting liquid extracts; differences in the methods for determining metals concentrations in the extracts are not expected to affect the results greatly.

For all metals except mercury, the total method determined total metal concentrations in the soil by nearly complete digestion of the solid phase of soil samples. At least 95 percent of the solid material was digested by hydrochloric, nitric, hydrofluoric, and perchloric acids (Fishman and Friedman, 1985; and Briggs, 1990). The digested material was then analyzed by inductively-coupled plasma emission spectrometry (ICPES). Samples were also analyzed by hydride-generation atomic-absorption spectrometry (HGAAS) to determine total arsenic, antimony, and selenium concentrations (Welsch and others, 1990). Total mercury concentrations in the soil were determined from a partial digestion of the solid phase. Samples were digested with nitric acid and sodium dichromate, and the mercury in solution was reduced and vaporized and then analyzed by cold-vapor atomic-absorption spectrometry (CVAAS) (O'Leary and others, 1990). These analyses were performed by the Geologic Division Laboratory of the USGS in Arvada, Colo.

The total-recoverable method used a digestion procedure involving a mixture of nitric and hydrochloric acids that removes most material bound by surficial coatings on soil particles but removes less than 95 percent of the metals from the mineral matrix (method 3050; U.S. Environmental Protection Agency, 1986). This method is commonly used by regulatory agencies to determine the

amount of material that ultimately may be bioavailable. Concentrations of arsenic in the extracts were determined by graphite-furnace atomic-absorption spectrometry (GFAAS), and concentrations of mercury were determined by CVAAS. The remaining metals were determined by ICPES. Determinations of total-recoverable selenium for selected samples used HGAAS to obtain a lower reporting limit (Randy Knox, Washington State Department of Ecology, oral commun., 1993). Analysis by this method and the leaching methods described in the following paragraphs was performed by Ecology's Manchester Environmental Laboratory in Manchester, Wash.

Metal concentrations were also determined by three different leaching methods. Each method was designed to estimate the solubility and mobility of organic and inorganic components in contaminated soils. The ASTM method used was D3987-85 (American Society for Testing and Materials, 1985), in which distilled water was mixed with the soil (solution ratio: 70 grams of soil to 1.4 liters of water) and shaken for approximately 18 hours, and then the solution was extracted, filtered, preserved overnight with nitric acid, and analyzed the next day. The EP-TOX method (method 1310; U.S. Environmental Protection Agency, 1986), which was also used, was the same as the ASTM leaching procedure, except that it used a 0.5 normal acetic acid solution rather than distilled water as the solvent and it maintained the pH of the solution at 5. The TCLP method (method 1311; U.S. Environmental Protection Agency, 1990a, b) used in this study, like the EP-TOX method, used an acetic acid solution rather than distilled water and maintained the solution pH at 5. In addition, the TCLP method involved a stronger acetic acid solution and sodium hydroxide, which allowed for greater control of the solution pH. As a result, the TCLP method achieved a solution pH of 5 more consistently than in the EP-TOX method. Concentrations of mercury in the leachate sample were determined by CVAAS, and the remaining metals in the leachate were determined by ICPES.

Particle-size distributions of the soils were determined for grains between 63 μm and 19 mm by the USGS Cascades Volcano Observatory sediment laboratory in Vancouver, Wash. Samples were dried and then sieved through screens with mesh openings of 16, 8, 4, 2, 1, 0.5, 0.25, 0.125, and 0.063 mm (described by Guy, 1977).

Total carbon concentrations were determined by measuring the amount of material volatilized from a complete combustion of a sample split. Concentrations of inorganic carbon were determined by measuring the amount of material dissolved from applications of hydrochloric acid to a sample, and organic carbon was

calculated as the difference between total and inorganic carbon (Wershaw and others, 1987). The determinations were performed by the USGS National Water Quality Laboratory in Arvada, Colo.

Soil-solution pH was determined by project personnel using two different methods. A 1:1 solution by weight of soil to deionized water (10 grams soil, 10 mL, milliliters, of water) was made from a sample split and was allowed to equilibrate for 30 minutes, after which the solution was mixed and the pH measured. The second method used the same solution. After the first pH measurement, 1 mL of 1 molar calcium chloride was added to the solution. The sample was then mixed and allowed to equilibrate for an additional 30 minutes, after which the solution was mixed again and the second pH measurement was made.

Analytical Precision

The analytical precision of laboratory determinations was calculated from differences between laboratory results for duplicate samples (table 3). The percent difference between a sample value and its duplicate was calculated by dividing the absolute difference between the sample and duplicate by the mean value for the duplicate pair and multiplying by 100. An average difference for a metal was not calculated if the concentration in one or more duplicates was less than the laboratory minimum reporting level.

The ranges of precision for the total and total-recoverable methods were similar, about 0 to 20 percent; however, the precision of the total method was typically about twice as good as of the total-recoverable method. The precision for the ASTM, EP-TOX, and TCLP methods was typically much less than for either the total or total-recoverable methods and ranged from 0 to 179 percent from metal to metal. The large variance observed in analytical precision for the three leaching methods could, in part, be due to the fact that only one duplicate pair was used to test precision for these methods. Regardless, for this study, determinations of background concentrations of metals in soils based on leaching procedures have a much larger uncertainty than background concentrations of metals determined by the total and total-recoverable methods.

DETERMINATION OF BACKGROUND METALS CONCENTRATIONS

All data from this study are presented in tables A1 to A4 at the end of this report. Summary statistics of the data are presented to illustrate the magnitude and variability of the concentrations of specific metals on a statewide basis as determined by the five laboratory methods. The data for each metal were tested to determine if they are normally or log-normally distributed, and other statistical methods were used to demonstrate differences in the concentrations of metals within or among regions. Relations between the concentrations of metals determined by the total and total-recoverable methods are also presented, and relations between metals and other soil characteristics are discussed. Finally, the results from the leaching procedures are compared and the analytical precision of the various methods are discussed.

Differences among the population means of metals concentrations among the 12 regions suggest that sample variance may be minimized by dividing the State into various regions or groups of regions. Minimizing sample variance would in turn minimize the number of samples required to determine accurate baseline metals concentrations. Although concentrations of some metals may differ significantly among regions, summary statistics for individual or groups of regions were not given in this report because of the small number of samples and because these regions may be the focus of future investigations. The data in table A2 are given in a format so that summary statistics of metals concentrations for individual or groups of regions may be calculated if needed. For the purpose of this report, summary statistics that include all data were calculated to provide an initial assessment of the magnitude and variability of metals concentrations for the entire State.

Strong associations between or among individual regions may provide useful information. If sample variance remains relatively low and sampling size increases, the accuracy of the estimated baseline metals concentrations will increase. Therefore grouping data, for example from regions A and F, that demonstrate a strong association may provide more accurate information than data generated for an individual region. However, other considerations, such as location, soils, parent material, and climate, should also be made when data from different groups are combined.

Table 3.--Average differences between metals concentrations determined in duplicate soil samples

["a" denotes that concentrations in one or more duplicates are less than laboratory minimum reporting level and differences were not computed; -- indicates no data; statistics for the total, total-recoverable, ASTM (American Society for Testing and Materials), EP-TOX (Extraction Procedure Toxicity Test), and TCLP (Toxicity Characteristic Leaching Procedure) methods were determined using 4, 7, 1, 1, and 1 pairs of duplicates, respectively]

Average difference, in percent ¹ , for indicated method of analysis					
Metal	Total	Total recoverable	ASTM	EP-TOX	TCLP
Silver	a	a	a	a	a
Aluminum	2	6	45	a	a
Arsenic	9	13	a	a	a
Gold	a	--	--	--	--
Barium	1	--	179	40	2
Beryllium	0	13	a	a	a
Bismuth	a	--	--	--	--
Calcium	4	--	--	--	--
Cadmium	a	a	a	a	a
Cerium	5	--	--	--	--
Cobalt	1	--	--	--	--
Chromium	6	10	a	a	a
Copper	8	7	a	a	a
Europium	a	--	--	--	--
Iron	5	6	a	40	67
Gallium	3	--	--	--	--
Holmium	a	--	--	--	--
Mercury	20	a	120	a	a
Potassium	4	--	--	--	--
Lanthanum	3	--	--	--	--
Lithium	4	--	--	--	--
Magnesium	2	--	--	--	--
Manganese	2	8	a	a	0
Molybdenum	a	--	--	--	--
Sodium	8	--	--	--	--
Niobium	17	--	--	--	--
Neodymium	6	--	--	--	--
Nickel	7	15	a	a	a
Phosphorus	2	--	--	--	--
Lead	8	18	a	a	a
Antimony	12	a	a	a	a
Scandium	4	--	--	--	--
Selenium	12	a	a	a	a
Tin	a	--	--	--	--
Strontium	3	--	--	--	--

Table 3.--Average differences between metals concentrations determined in duplicate soil samples--Continued

Metal	Average difference, in percent ¹ , for indicated method of analysis				
	Total	Total recoverable	ASTM	EP-TOX	TCLP
Tantalum	a	--	--	--	--
Thorium	0	--	--	--	--
Titanium	3	--	--	--	--
Thallium	--	a	a	a	a
Uranium	a	--	--	--	--
Vanadium	5	--	--	--	--
Yttrium	1	--	--	--	--
Ytterbium	0	--	--	--	--
Zinc	2	7	a	a	18

¹ Average of absolute values of differences, in percent, between concentrations in duplicate samples.

Regions A and F are located adjacent to each other and lie primarily within or adjacent to the Puget Sound Lowland (fig. 2). Soils in region A formed primarily in marine sediments, which were derived from a volcanic range to the east of the present Washington coast (Pringle, 1986). Similar marine sediments are also exposed in the northern part of the Cascade Range of Washington and British Columbia and on Vancouver Island (Wolfe and McKee, 1972). During the Vashon stage of the upper Pleistocene Fraser Glaciation, a lobe of the Cordilleran ice sheet extended into the Puget Lowland, which resulted in deposits of till and various outwash sediments that are found in region F today. The glacial sediments were derived from material originally located in the northern part of the Cascade Range and Western British Columbia, which indicates that the soils in regions A and F developed in parent material derived from similar sources.

Based on this information and the results of the Fisher's Least Significant Difference test and the Cluster analyses, further investigation could provide more definitive relations between regions such as A and F and among O, P, and R, which were shown to be associated and similarly could test whether regions that were not associated with other regions can be characterized individually. These investigations could continue to include determinations of other soil characteristics (for example, particle size, organic carbon) as well as additional analyses, such as cation-exchange capacity so that mechanisms controlling the chemistry and the associated distribution of metals in the soil may be better understood.

Summary Statistics

Summary statistics of metals concentrations in soils measured in this study are listed in tables 4 through 8. Each table gives the summary statistics of unadjusted and log-transformed values of the data for all metals determined by one of the laboratory methods. When the concentration of a metal in a sample was smaller than the laboratory's minimum reporting level, the minimum reporting level was used for calculating statistics, and the statistics were qualified as less than or greater than the value given.

The concentrations of metals in uncontaminated soils in Washington State varied by as much as 62-fold. However, concentrations of metals determined by the total method were consistently greater and varied less than values for metals determined by the total-recoverable, ASTM, EP-TOX, or TCLP methods (see fig. 3). Mean concentrations of individual metals determined by the total-recoverable method ranged from 7 to 56 percent of mean concentrations determined by the total method, and detectable concentrations of metals determined by the ASTM or TCLP methods were typically less than 1 percent of the concentrations determined by the total method. Total concentrations of mercury and nickel and total-recoverable concentrations of nickel, chromium, and copper displayed the greatest variability, and all have arithmetic standard deviations greater than two-thirds of their respective arithmetic means (tables 4 and 5). Concentrations of other metals, such as aluminum and barium

determined by the total method, varied less; both have arithmetic standard deviations less than one-third of their respective means (table 4). The box plots of figure 3 demonstrate the variability for the entire data set but do not illustrate how the concentrations of metals differ among regions and how values for a specific region may influence the variability observed for all the data. Figures 4 to 20 show variations of concentration within and among regions. For example, concentrations of mercury, chromium, copper, and iron vary greatly among regions, whereas concentrations of other metals, such as zinc, lead, or arsenic, vary less, although arsenic concentrations within a given region may be fairly variable. Other metals, such as aluminum, exhibit consistent concentrations when analyzed by the total method but greater variability when analyzed by the other four methods. Particle size, carbon content, and soil-solution pH are also highly variable throughout the State. For example, region C is composed almost entirely of sand, whereas regions O and P contain greater amounts of silt and clay than other regions (see fig. 21). Carbon concentrations generally are greater in samples collected in the regions west of the Cascade Range than those collected in the east, and the soil-solution pH is also more acidic west of the Cascade Range and more alkaline east of the Cascade Range (see figs. 22 and 23). The variability of TPH and PCB's in soils could not be determined because the concentrations of each were always less than the laboratory's minimum reporting level.

Frequency Distributions of Metals Concentrations

Understanding the nature of the data and applying the proper statistical analyses requires knowing whether the sampled data came from a population that follows a normal distribution. The probability plot correlation coefficient test (Looney and Gullidge, 1985a, b) was used to test whether the metals concentrations determined by the total and total-recoverable methods are from populations that are normally or log-normally distributed. The probability plot correlation coefficient test was used to test two null hypotheses: (1) that the data were sampled from populations that are normally distributed and (2) that the data were sampled from populations that are log-normally distributed. Correlation coefficients between the data and their respective normal quantiles (the x axis on a probability plot) were determined and compared to that of a normal distribution, in which the coefficient would be 1.0 (Looney and Gullidge, 1985a, b). A null hypothesis was rejected when the correlation coefficient was sufficiently small such that there was less than a 5-percent chance of rejecting the null hypothesis when it should not be rejected.

When one or more concentrations were below the laboratory minimum reporting level, normal quantiles were computed using all the data; however, data for samples with concentrations less than the minimum reporting level were not included in computations of the correlation coefficients.

Concentrations of 13 metals determined by the total method and of 5 metals determined by the total-recoverable method in this study were determined to have been sampled from populations that were distributed log-normally (at a 95 percent confidence level) (table 9). Concentrations of four metals determined by the total method and three total-recoverable metals were found to have been sampled from populations that were distributed normally. The concentrations of three metals determined by the total method were determined to have been sampled from populations that were neither normally nor log-normally distributed, and the population distributions for concentrations of three other metals could not be determined because all values were less than laboratory reporting limits. Concentrations of 12 metals determined by the total method and of 3 metals determined by the total-recoverable method were apparently more nearly log-normally than normally distributed.

Metals concentrations in various igneous rocks, sampled from different locations, have been shown to be sampled from populations that are not normally distributed (Ahrens, 1954). Furthermore, Ahrens (1954) found that the sample distributions became normal (or nearly normal) when the data were log-transformed (that is, log-normally distributed). Kulp and others (1952) and David (1977) observed similar sample frequency distributions for metals concentrations in marine and other sediments as well as various igneous rocks. Therefore, it is not surprising that concentrations of various metals in soils are likewise log-normally distributed, as observed in this study. This distribution would especially be true for those metals, specifically transition metals, that are primarily contained within the mineral matrices. In this study, all transition metals, with the exceptions of gallium determined by the total method and lead and manganese determined by the total-recoverable method, are more nearly log-normally than normally distributed. The same is true for most alkali and alkali earths, with the exceptions of barium, potassium, and strontium determined by the total method and of beryllium determined by the total-recoverable method. The statistical tests presented in the following sections are non-parametric because the majority of metals concentrations were either sampled from populations that are decidedly log-normally distributed or more nearly log-normally than normally distributed.

Table 4.--Summary statistics for concentrations of metals in soils in Washington as determined by the total method

[Concentrations are in milligrams per kilogram of dry soil (except values for Al, Ca, Fe, K, Mg, Na, P, and Ti, which are given in percent); -- indicates statistic not computed because concentrations in all samples were less than laboratory's minimum reporting value; <, less than]

Metal	Total number of samples/ detects ¹	Arithmetic mean	Geometric mean	Median	Arithmetic standard deviation	Geometric deviation factor ²	Minimum	Maximum	90th percentile
Silver	37/0	<2.0	<2.0	<2.0	--	--	<2.0	<2.0	<2.0
Aluminum	37/37	8.1	8.0	7.9	1.1	1.1	6.7	11.0	10.0
Arsenic	37/37	6.6	5.3	5.5	4.2	2.0	.8	20.0	13.0
Gold	37/0	<8	<8	<8	--	--	<8	<20	<8
Barium	37/37	600	580	650	140	1.3	300	920	760
Beryllium	37/34	<1.5	<1.5	2.0	>.5	>1.4	<1.0	2.0	2.0
Bismuth	37/0	<10	<10	<10	--	--	<10	<20	<10
Calcium	37/37	2.0	1.8	1.8	1.0	1.7	.4	5.5	3.7
Cadmium	37/4	<2.2	<2.2	<2.0	>.9	>1.3	<2.0	6.0	<2.3
Cerium	37/37	64	61	64	17	1.3	26	110	86
Cobalt	37/37	20	18	17	10	1.6	8	48	36
Chromium	37/37	100	82	69	97	1.9	28	540	190
Copper	37/37	36	32	29	20	1.5	13	120	56
Europium	37/3	<2	<2	<2	>.3	>1.1	<2	<4	<2
Iron	37/37	5.0	4.7	4.6	1.8	1.4	2.5	9.3	7.9
Gallium	37/37	20	19	20	4	1.2	10	28	24
Mercury	37/37	.4	.09	.06	1.3	3.4	.04	6.0	.4
Holmium	37/0	<4	<4	<4	--	--	<4	<4	<4
Potassium	37/37	1.5	1.4	1.6	.5	1.5	.5	2.3	2.2
Lanthanum	37/37	35	33	33	10	1.3	15	61	48
Lithium	37/37	34	32	29	13	1.4	20	89	50
Magnesium	37/37	1.3	1.1	1.1	.6	1.5	.6	3.5	2.0
Manganese	37/37	790	750	690	280	1.4	410	1,600	1,320
Molybdenum	37/7	<2	<2	<2	>.4	>1.1	<2	<4	<2
Sodium	37/37	1.8	1.7	1.7	.9	1.4	.9	6.2	2.3
Niobium	37/36	<9	<9	9	>3	>1.4	<4	14	13

Table 4.--Summary statistics for concentrations of metals in soils in Washington as determined by the total method--Continued

Metal	Total number of samples/detects ¹	Arithmetic mean	Geometric mean	Median	Arithmetic standard deviation	Geometric deviation factor ²	Minimum	Maximum	90th percentile
Neodymium	37/37	32	32	33	8	1.3	16	55	43
Nickel	37/37	46	31	27	75	2.1	11	470	74
Phosphorus	37/37	.1	.1	.1	.1	1.7	.02	.5	.2
Lead	37/37	13	12	12	5	1.5	4	36	18
Antimony	37/36	<1.4	<1.3	1.3	>.7	>1.5	<.6	3.8	3.8
Selenium	37/29	<.3	<.2	.1	>.3	>2.3	<.1	1.2	1.0
Scandium	37/37	19	17	16	8	1.5	9	38	34
Tin	37/0	<5	<5	<5	--	--	<5	<10	<5
Strontium	37/37	290	260	290	86	1.4	92	460	370
Tantalum	37/0	<41	<41	<40	--	--	<40	<80	<40
Thorium	37/36	<9	<9	9	<3	>1.4	<5	17	14
Titanium	37/37	.7	.6	.6	.3	1.4	.3	1.3	1.2
Uranium	37/0	<100	<100	<100	--	--	<100	<200	<100
Vanadium	37/37	140	130	130	69	1.6	57	370	254
Yttrium	37/37	23	22	23	7	1.4	10	44	36
Ytterbium	37/37	2	2	2	1	1.5	1	4	4
Zinc	37/37	100	95	89	41	1.4	61	280	140

¹ Detects are the number of samples with concentrations greater than the laboratory reporting limit.

² To obtain concentration at n geometric deviations above and below the geometric mean, multiply and divide the geometric mean by the geometric deviation factor to the nth power. For example, barium concentrations at two geometric deviations above and below the geometric mean are

$$580 \times (1.3)^2 = 980 \text{ mg/kg, and } 580/(1.3)^2 = 340 \text{ mg/kg, respectively.}$$

Table 5.--Summary statistics for concentrations of metals in soils in Washington as determined by the total-recoverable method

[Concentrations are in milligrams per kilogram of dry soil (except Al and Fe, which are in percent); -- indicates statistic not computed because concentrations in most samples were less than laboratory's minimum reporting value]

Metal	Total number of samples/detects ¹	Arithmetic mean	Geometric mean	Median	Arithmetic standard deviation	Geometric deviation factor ²	Minimum	Maximum	90th percentile
Silver	60/12	<0.2	<0.2	<0.2	>0.1	>1.3	<0.2	0.6	0.3
Aluminum	60/60	2.1	1.8	1.7	1.2	1.8	.6	5.4	4.0
Arsenic	60/59	<3.4	<2.8	2.8	>2.2	>2.0	<.5	9.4	6.8
Beryllium	60/60	.6	.5	.5	.3	1.9	<.1	1.4	.9
Cadmium	60/0	<.2	<.2	<.2	--	--	<.2	<.2	<.2
Chromium	60/60	30	21	18	44	2.1	5	310	51
Copper	60/60	20	17	19	14	1.8	4	99	31
Iron	60/60	2.5	2.3	2.3	1.1	1.5	.9	6.3	4.2
Mercury	60/52	<.027	<.016	.013	<.032	>2.7	<.004	.19	.06
Manganese	60/60	420	370	380	190	1.7	78	930	680
Nickel	60/60	25	17	16	46	2.0	6	360	34
Lead	60/60	7	7	7	3	1.6	2	14	12
Antimony	60/0	<3.0	<3.0	<3.0	--	--	<3.0	<3.0	<3.0
Selenium	60/0	<.6	<.6	<.5	--	--	<.5	<5.4	<5.0
Thallium ³	60/21	--	--	<5.0	--	--	<5.0	>14.0	>9.0
Zinc	60/60	50	47	45	19	1.4	21	116	80

¹ Detects are the number of samples with concentrations greater than the laboratory reporting limit.

² To obtain concentrations at n geometric deviations above and below the geometric mean, multiply and divide the geometric mean by the geometric deviation factor to the nth power. For example, nickel concentrations at two geometric deviations above and below the geometric mean are

$$17 \times (2.0)^2 = 68 \text{ mg/kg, and } 17/(2.0)^2 = 4.3 \text{ mg/kg, respectively.}$$

³ All detected thallium values were estimated to be greater than those values given.

Table 6.--Summary statistics for concentrations of metals in soils in Washington as determined by the American Society for Testing and Materials method D3987-85

[Concentrations are in milligrams per kilogram of dry soil; to convert to values in milligrams per liter of leachate, divide values given by 20; -- indicates statistic not computed because concentrations in most samples were less than laboratory's minimum reporting value]

Metal	Total number of samples/ detects ¹	Arithmetic mean	Geometric mean	Median	Arithmetic standard deviation	Geometric deviation factor ²	Minimum	Maximum	90th percentile
Silver	12/0	<0.04	<0.04	<0.04	--	--	<0.04	<0.04	<0.04
Aluminum	12/9	<2.0	<1.8	1.8	>0.9	>1.6	<1	3.6	3.5
Arsenic	12/1	<.7	<.7	<.6	>.3	>1.3	<.6	1.6	<1.2
Barium	12/12	.7	.5	.4	.6	2.2	.1	2.4	2.0
Beryllium	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Cadmium	12/3	<.04	<.04	<.04	>.003	>1.1	<.04	<.05	.05
Chromium	12/0	<1	<1	<1	--	--	<1	<1	<1
Copper	12/1	<.4	<.4	<.4	>1	>1.2	<.4	.7	<.6
Iron	12/10	<1.8	<1.1	.9	>2.0	>2.6	<.4	6.3	6.0
Mercury	12/12	.003	.003	.003	.001	1.3	.002	.004	.004
Manganese	12/1	<.4	<.4	<.4	>1	>1.2	<.4	.7	<.6
Nickel	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Lead	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Antimony	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Selenium	12/0	<1	<1	<1	--	--	<1	<1	<1
Thallium	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Zinc	12/4	<.5	<.5	<.4	>.4	>1.3	<.4	.8	.7

¹ Detects are the number of samples with concentrations greater than the laboratory reporting limit.

² To obtain concentrations at n geometric deviations above and below the geometric mean, multiply and divide the geometric mean by the geometric deviation factor to the nth power. For example, barium concentrations at two geometric deviations above and below the geometric mean are

$$0.5 \times (2.2)^2 = 2 \text{ mg/kg, and } 0.5/(2.2)^2 = 0.1 \text{ mg/kg, respectively.}$$

Table 7.--Summary statistics for concentrations of metals in soils in Washington as determined by the Extraction Procedure Toxicity method

[Concentrations are in milligrams per kilogram of dry soil; to convert to values in milligrams per liter of leachate, divide values given by 20; -- indicates statistic not computed because concentrations in most samples were less than laboratory's minimum reporting value]

Metal	Total number of samples/detects ¹	Arithmetic mean	Geometric mean	Median	Arithmetic standard deviation	Geometric deviation factor ²	Minimum	Maximum	90th percentile
Silver	12/0	<0.04	<0.04	<0.04	--	--	<0.04	<0.04	<0.04
Aluminum	12/2	<2.9	<1.3	<1	>6.6	>2.5	<1	24	10.4
Arsenic	12/1	<.7	<.7	<.6	>.3	>1.3	<.6	1.6	<1.2
Barium	12/12	2.9	1.7	1.5	4.8	2.4	.8	18	10.5
Beryllium	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Cadmium	12/0	<.04	<.04	<.04	--	--	<.04	<.04	<.04
Chromium	12/0	<.1	<.1	<.1	--	--	<.1	<.1	<.1
Copper	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Iron	12/10	<.8	<.7	.7	>.5	>1.6	<.4	1.9	1.8
Mercury	12/0	<.0008	<.0008	<.0008	--	--	<.0008	<.0008	<.0008
Manganese	12/3	<.8	<.5	<.4	>1.1	>2.0	<.4	4.4	2.7
Nickel	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Lead	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Antimony	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Selenium	12/0	<1	<1	<1	--	--	<1	<1	<1
Thallium	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Zinc	12/11	<.6	<.6	.6	>.2	>1.4	<.4	1.1	1.1

¹ Detects are the number of samples with concentrations greater than the laboratory reporting limit.

² To obtain concentrations at n geometric deviations above and below the geometric mean, multiply and divide the geometric mean by the geometric deviation factor to the nth power. For example, barium concentrations at two geometric deviations above and below the geometric mean are

$$1.7 \times (2.4)^2 = 9.8 \text{ mg/kg, and } 1.7/(2.4)^2 = 0.3 \text{ mg/kg, respectively.}$$

Table 8.--Summary statistics for concentrations of metals in soils in Washington as determined by the Toxicity Characteristic Leaching Procedure

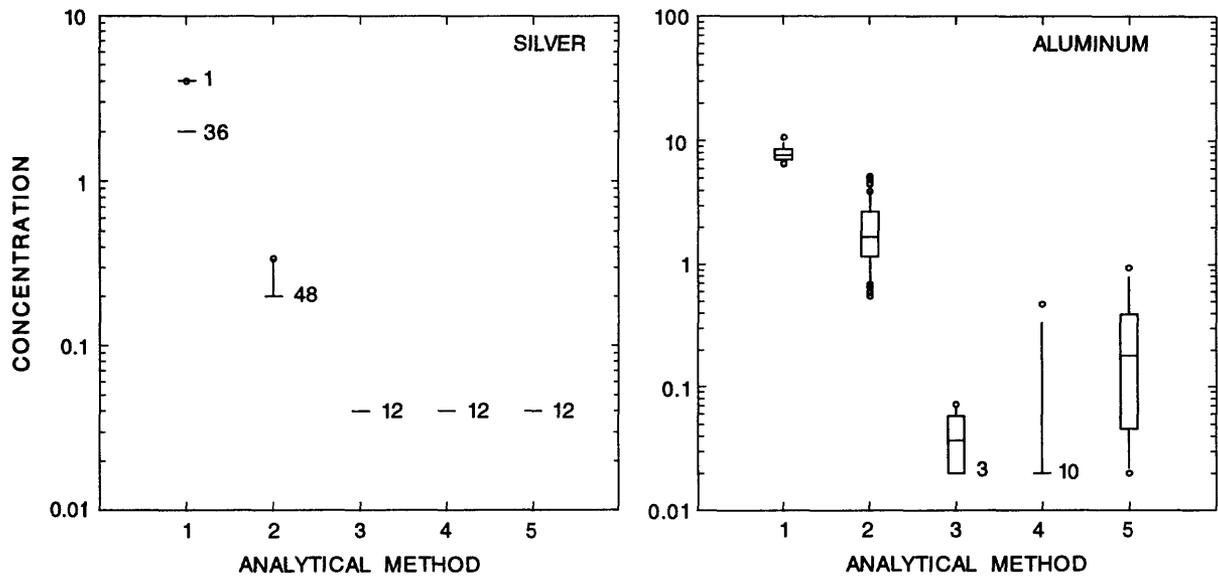
[Concentrations are in milligrams per kilogram of dry soil; to convert to values in milligrams per liter of leachate, divide values given by 20; -- indicates statistic not computed because concentrations in most samples were less than laboratory's minimum reporting value]

Metal	Total number of samples/detects ¹	Arithmetic mean	Geometric mean	Median	Arithmetic standard deviation	Geometric deviation factor ²	Minimum	Maximum	90th percentile
Silver	12/0	<0.04	<0.04	<0.04	--	--	<0.04	<0.04	<0.04
Aluminum	12/11	<12.7	<7.1	8.6	>13.2	>3.4	<1	47	37.7
Arsenic	12/1	<.7	<.7	<.6	>.5	>1.5	<.6	2.3	<1.6
Barium	12/12	11.1	9.9	11.1	5.0	1.7	3	19.1	18.9
Beryllium	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Cadmium	12/0	<.04	<.04	<.04	--	--	<.04	<.04	<.04
Chromium	12/0	<.1	<.1	<.1	--	--	<.1	<.1	<.1
Copper	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Iron	12/11	<2.8	<1.4	1.2	>4.8	>2.8	<.4	17.5	12.1
Mercury	12/0	<.001	<.001	<.001	--	--	<.001	<.001	<.001
Manganese	12/10	<2.0	<1.3	1.3	>1.8	>2.5	<.4	6.5	5.5
Nickel	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Lead	12/0	<.4	<.4	<.4	--	--	<.4	<.4	<.4
Antimony	12/3	<.4	<.4	<.4	>.02	>1.1	<.4	.5	.5
Selenium	12/0	<1	<1	<1	--	--	<1	<1	<1
Thallium	12/0	<.5	<.5	<.4	--	--	<.4	<2.0	<1.2
Zinc	12/12	1.6	1.5	1.7	.4	1.4	.7	2.1	2.1

¹ Detects are the number of samples with concentrations greater than the laboratory reporting limit.

² To obtain concentrations at n geometric deviations above and below the geometric mean, multiply and divide the geometric mean by the geometric deviation factor to the nth power. For example, barium concentrations at two geometric deviations above and below the geometric mean are

$$9.9 \times (1.7)^2 = 29 \text{ mg/kg, and } 9.9/(1.7)^2 = 3.4 \text{ mg/kg, respectively.}$$



EXPLANATION

- Individual value, greater than 90th percentile
- Individual value, less than 10th percentile
- 36 Horizontal bar denotes (laboratory reporting limit). Number of samples with concentrations less than values shown
- ANALYTICAL METHOD**
- 1 Total method: 37 samples, all units in milligrams per kilogram (mg/kg): except Aluminum and Iron, which are in percent
 - 2 Total recoverable method: 60 samples, all units in milligrams per kilogram (mg/kg): except Aluminum and Iron, which are in percent
 - 3 ASTM (American Society for Testing Materials, leaching test): 12 samples, all units in milligrams per kilogram (mg/kg)
 - 4 EP-TOX (Extraction Procedure Toxicity Test): 12 samples, all units in milligrams per kilogram (mg/kg)
 - 5 TCLP (Toxicity Characteristic Leaching Procedure): 12 samples, units in milligrams per kilogram (mg/kg)

Figure 3.--Concentrations of metals in soils of Washington State, determined by five laboratory methods.

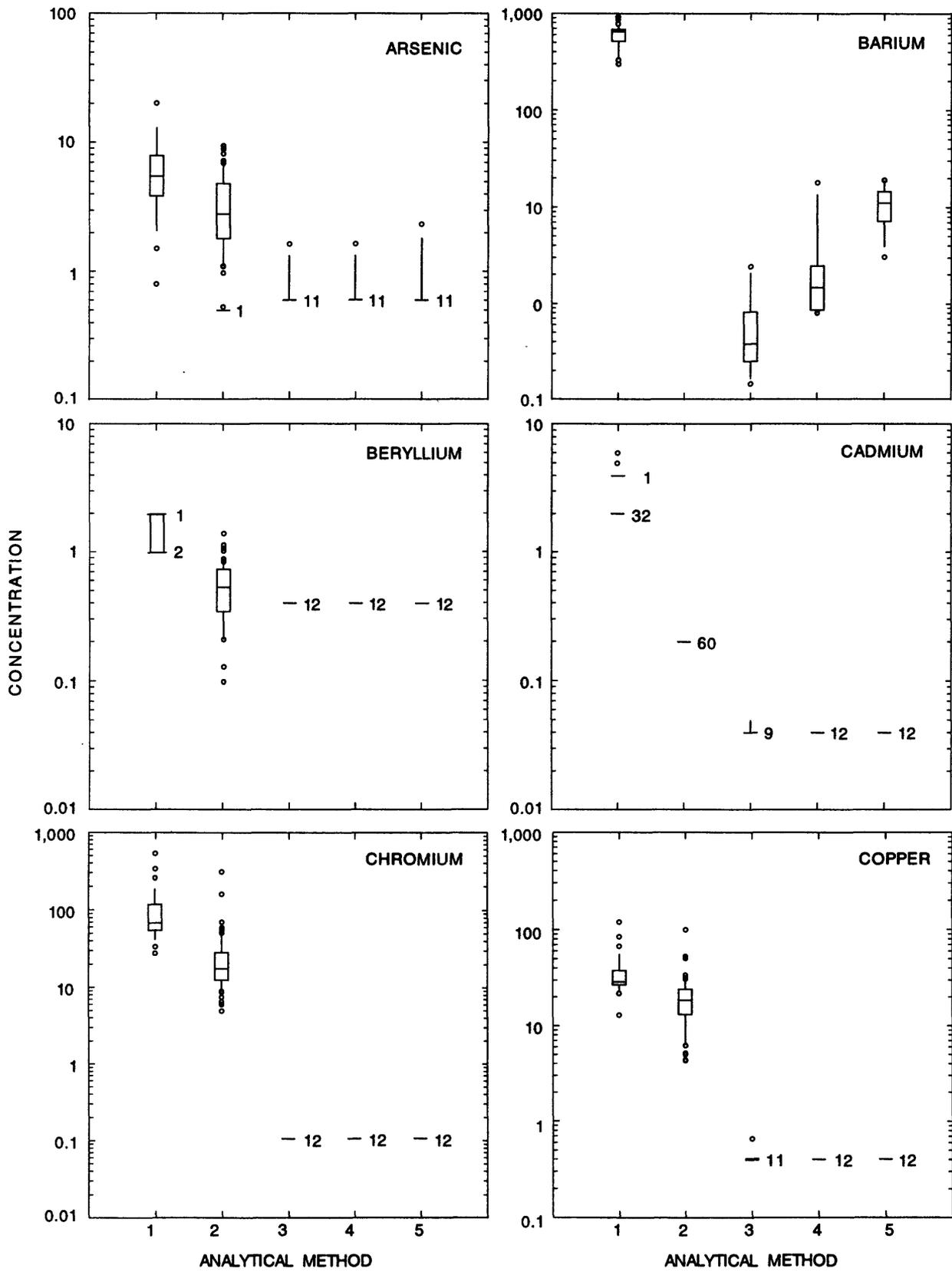


Figure 3.--Continued

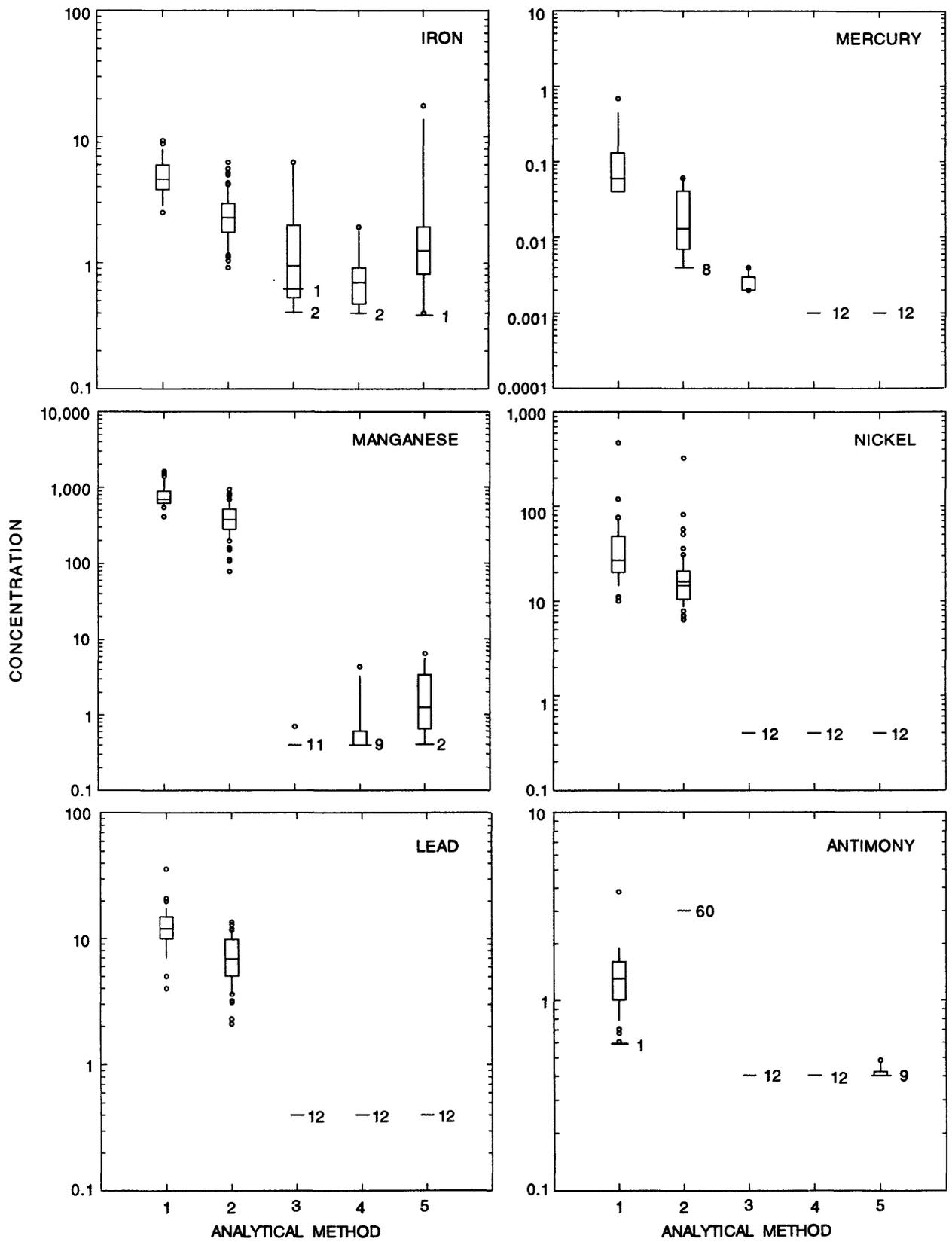


Figure 3.--Continued

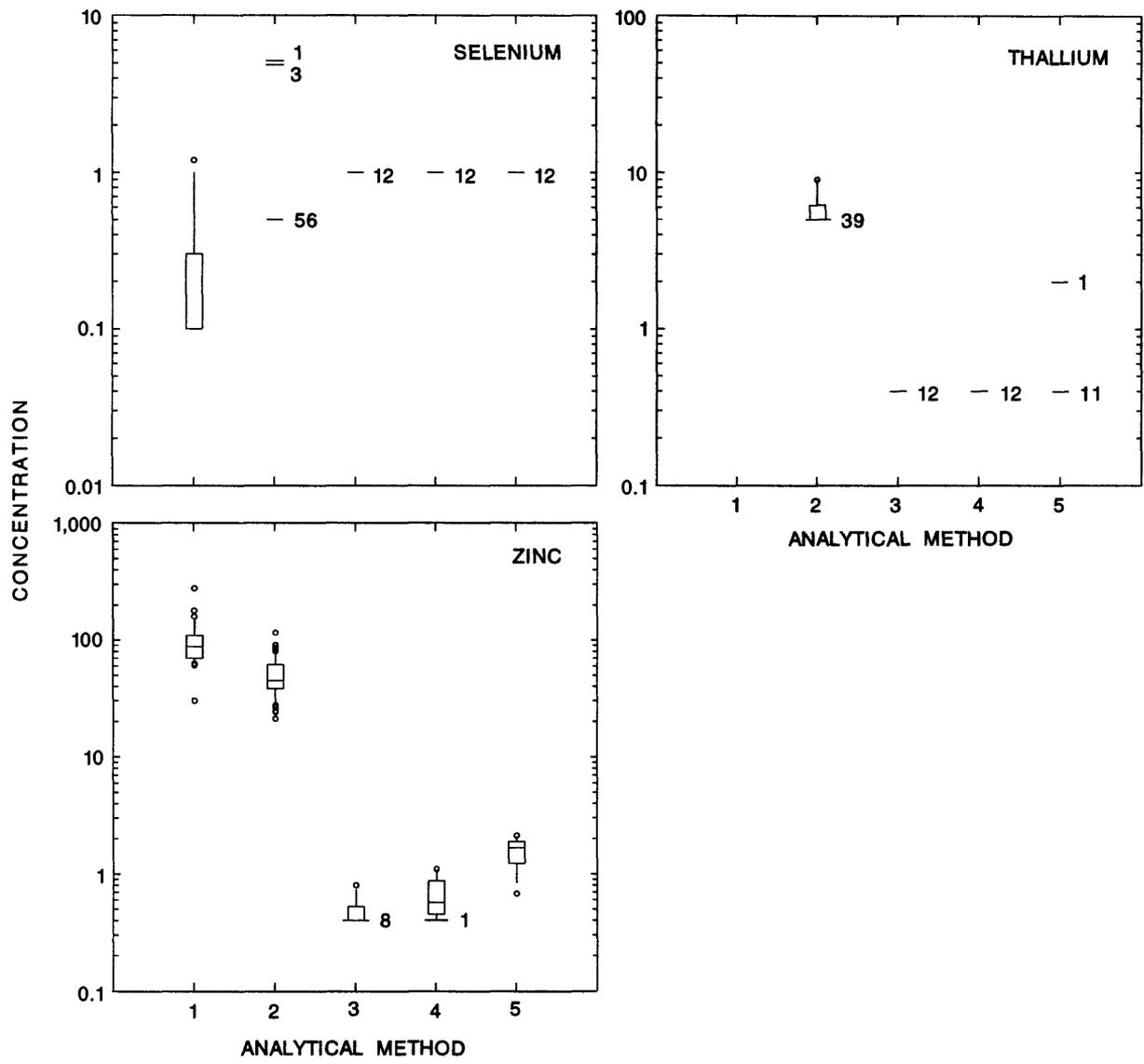


Figure 3.--Continued

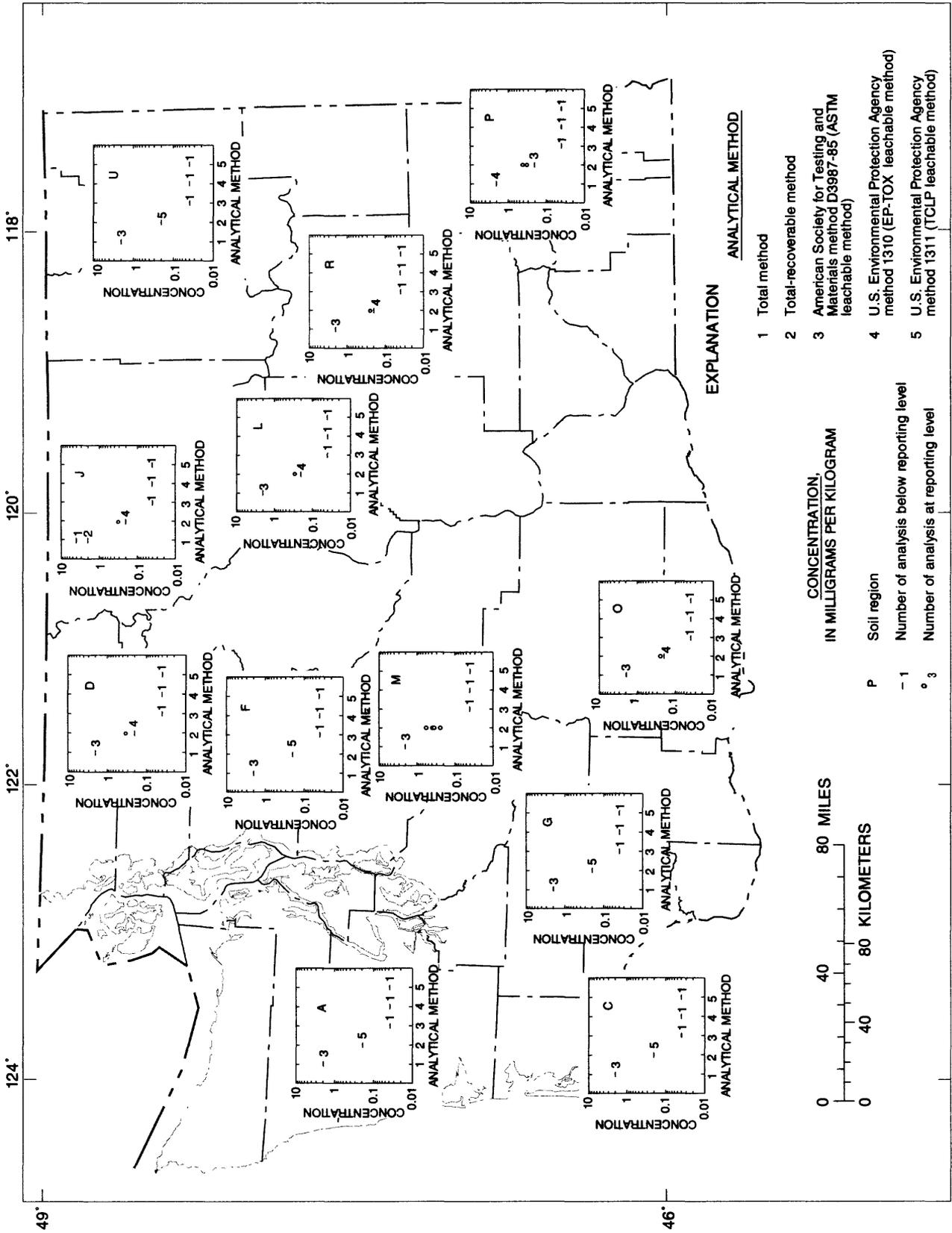


Figure 4.--State of Washington, county boundaries, and concentrations of silver determined by 5 analytical methods for 12 soil regions.

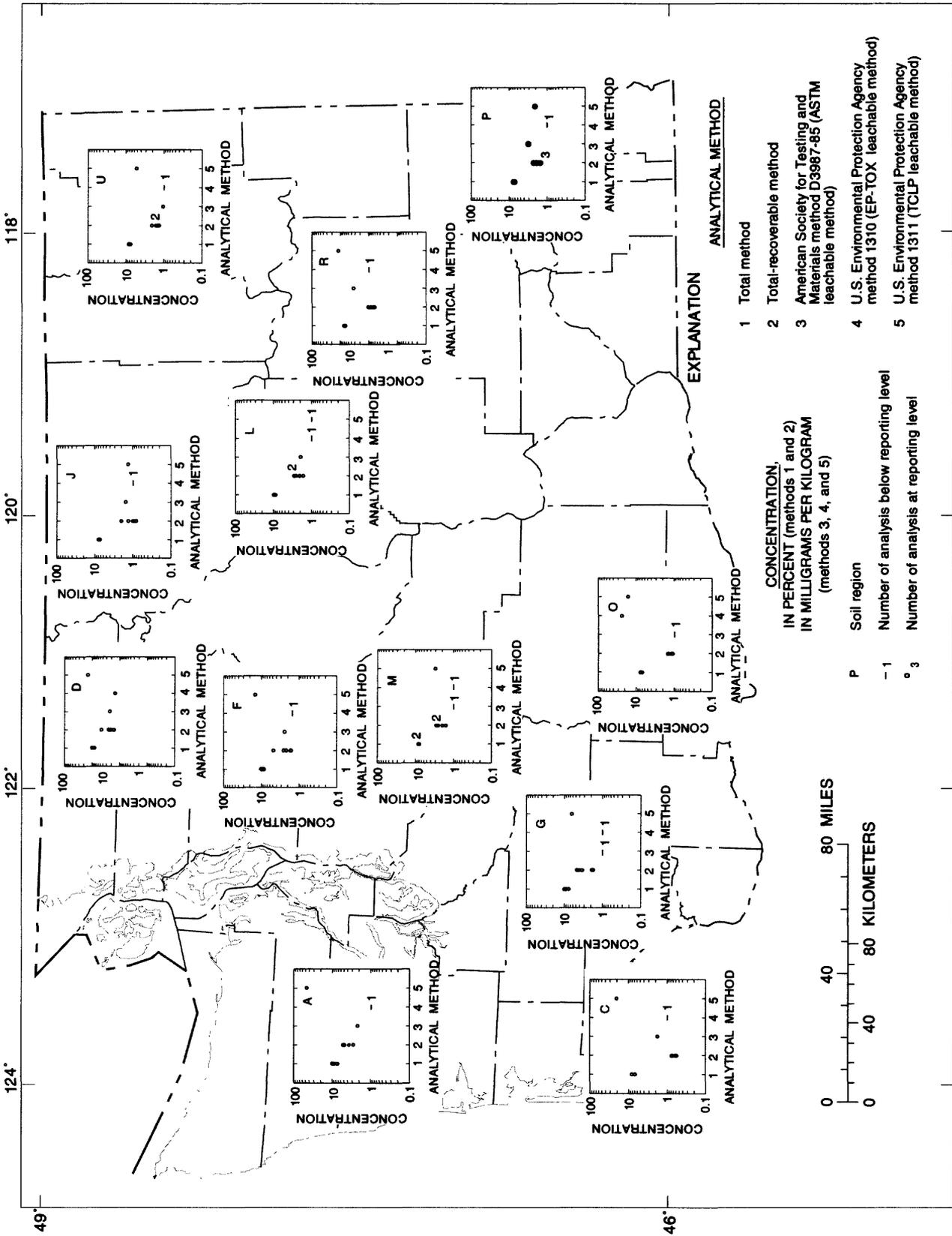


Figure 5.--State of Washington, county boundaries, and concentrations of aluminum determined by 5 analytical methods for 12 soil regions.

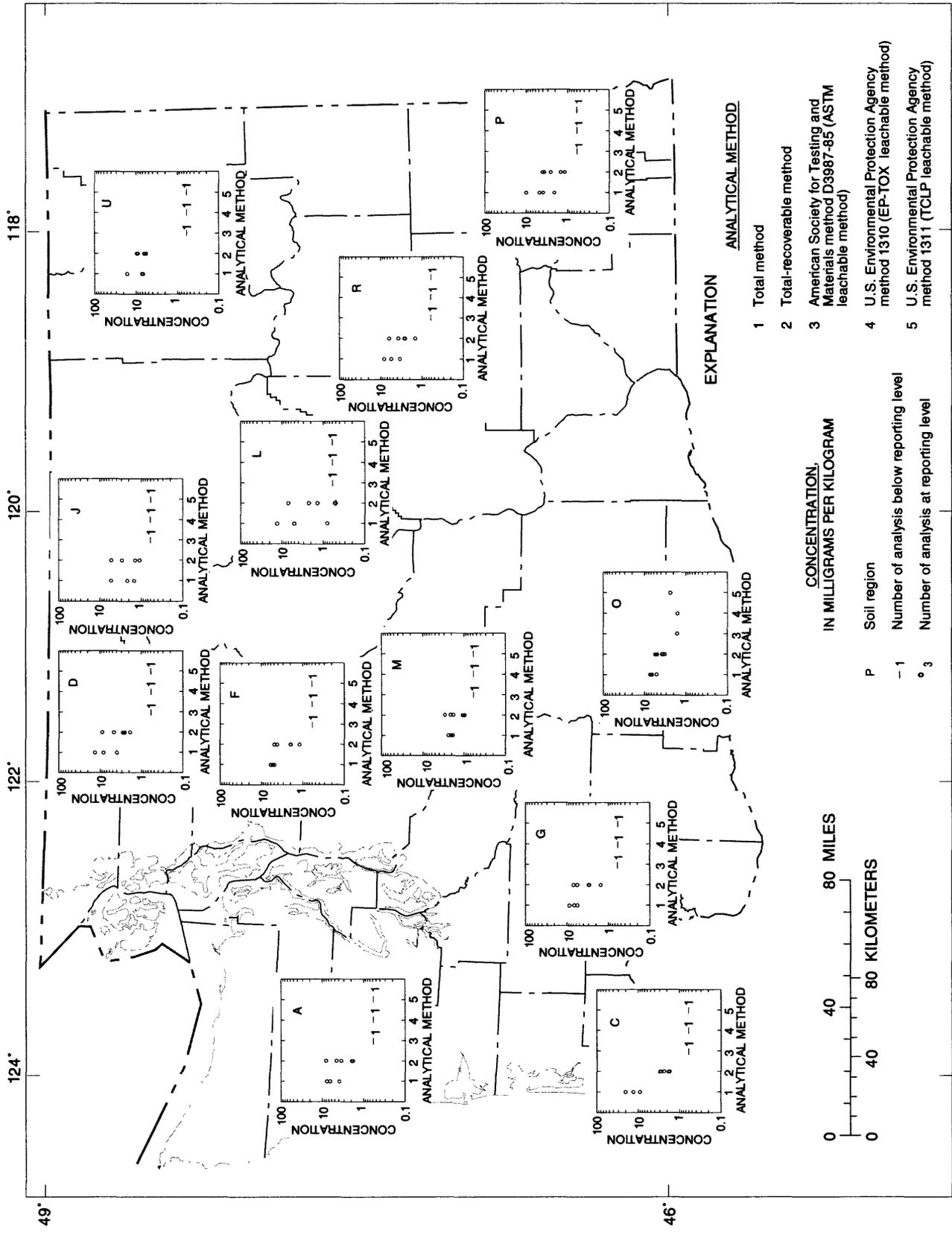


Figure 6.--State of Washington, county boundaries, and concentrations of arsenic determined by 5 analytical methods for 12 soil regions.

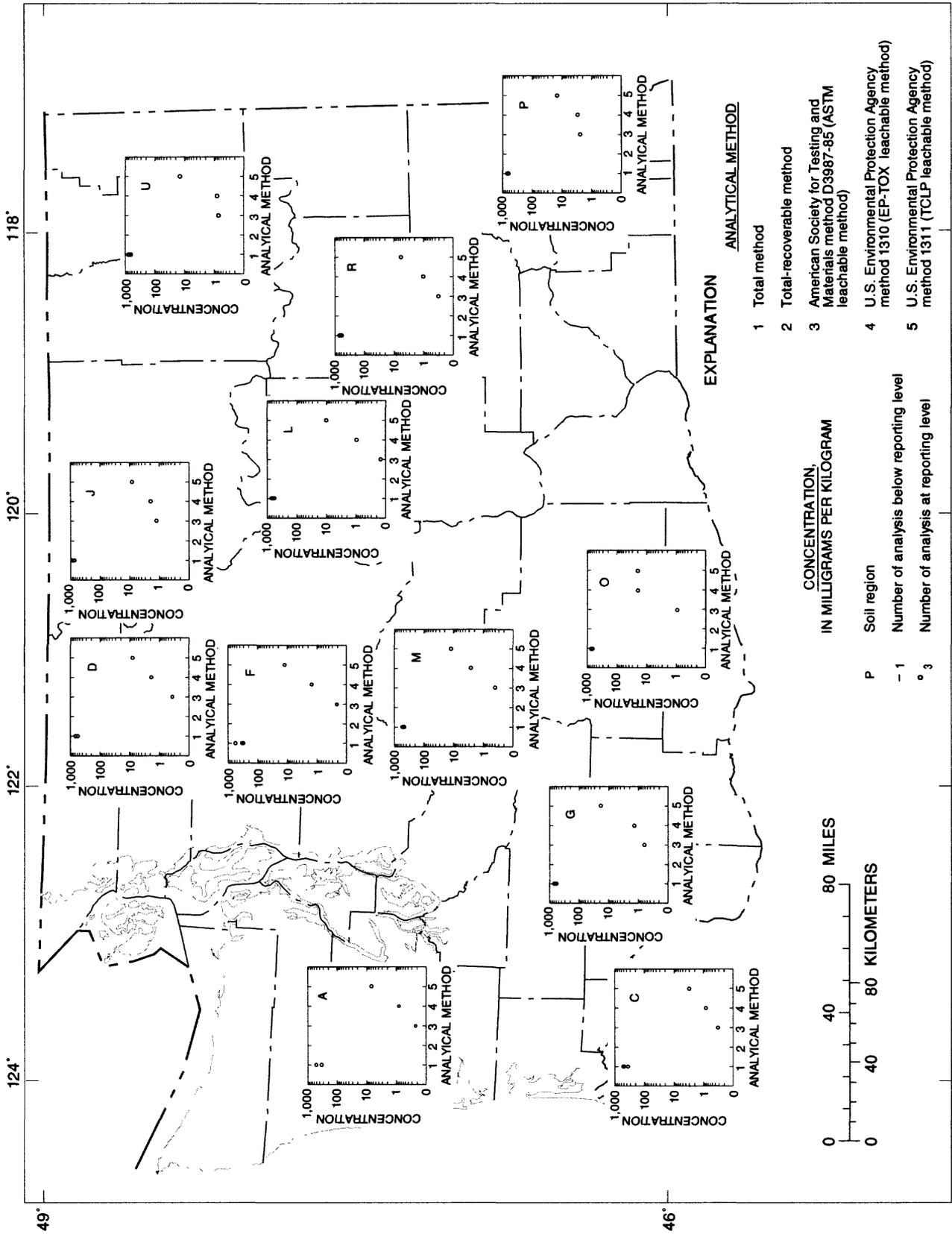


Figure 7.--State of Washington, county boundaries, and concentrations of barium determined by 5 analytical methods for 12 soil regions.

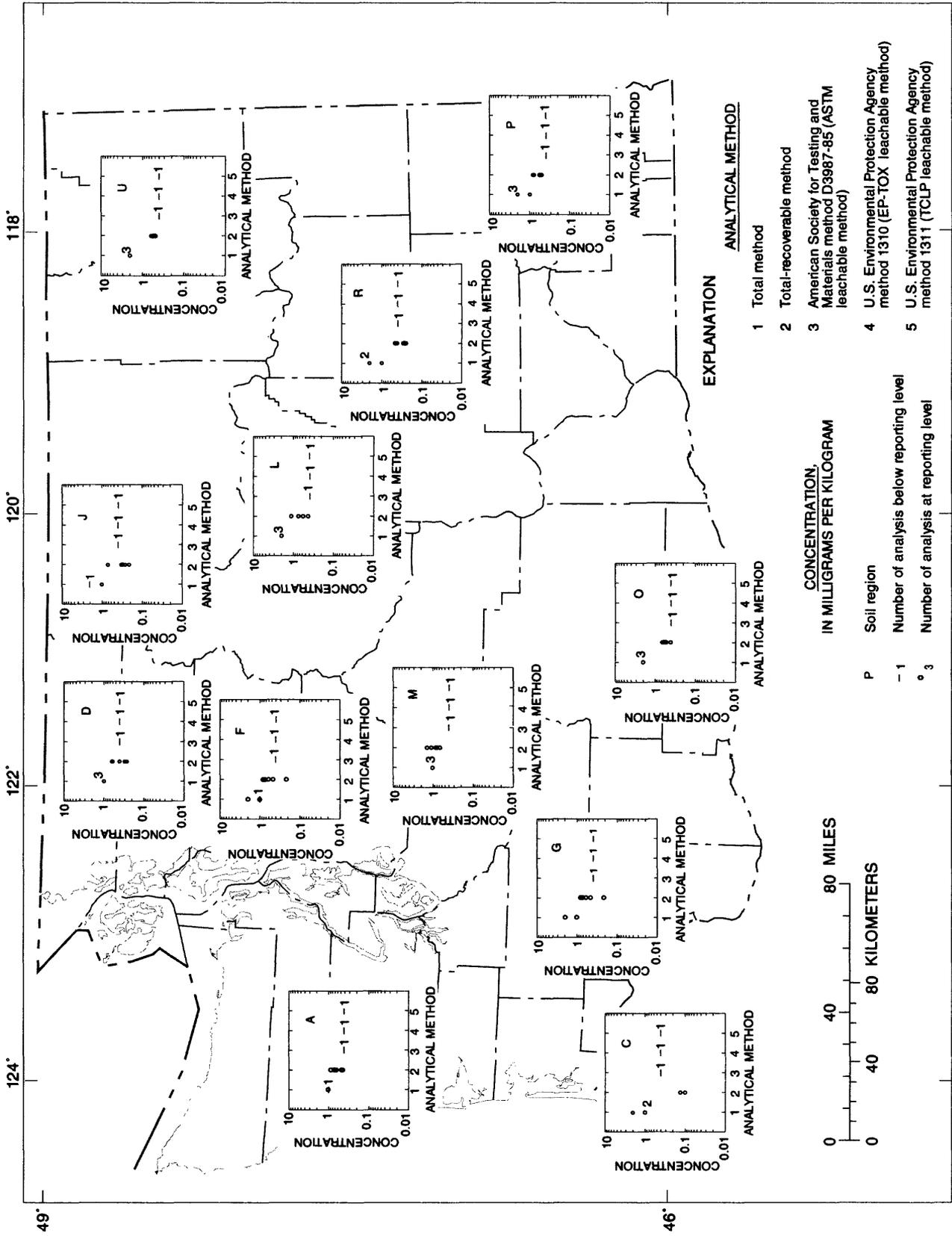


Figure 8.--State of Washington, county boundaries, and concentrations of beryllium determined by 5 analytical methods for 12 soil regions.

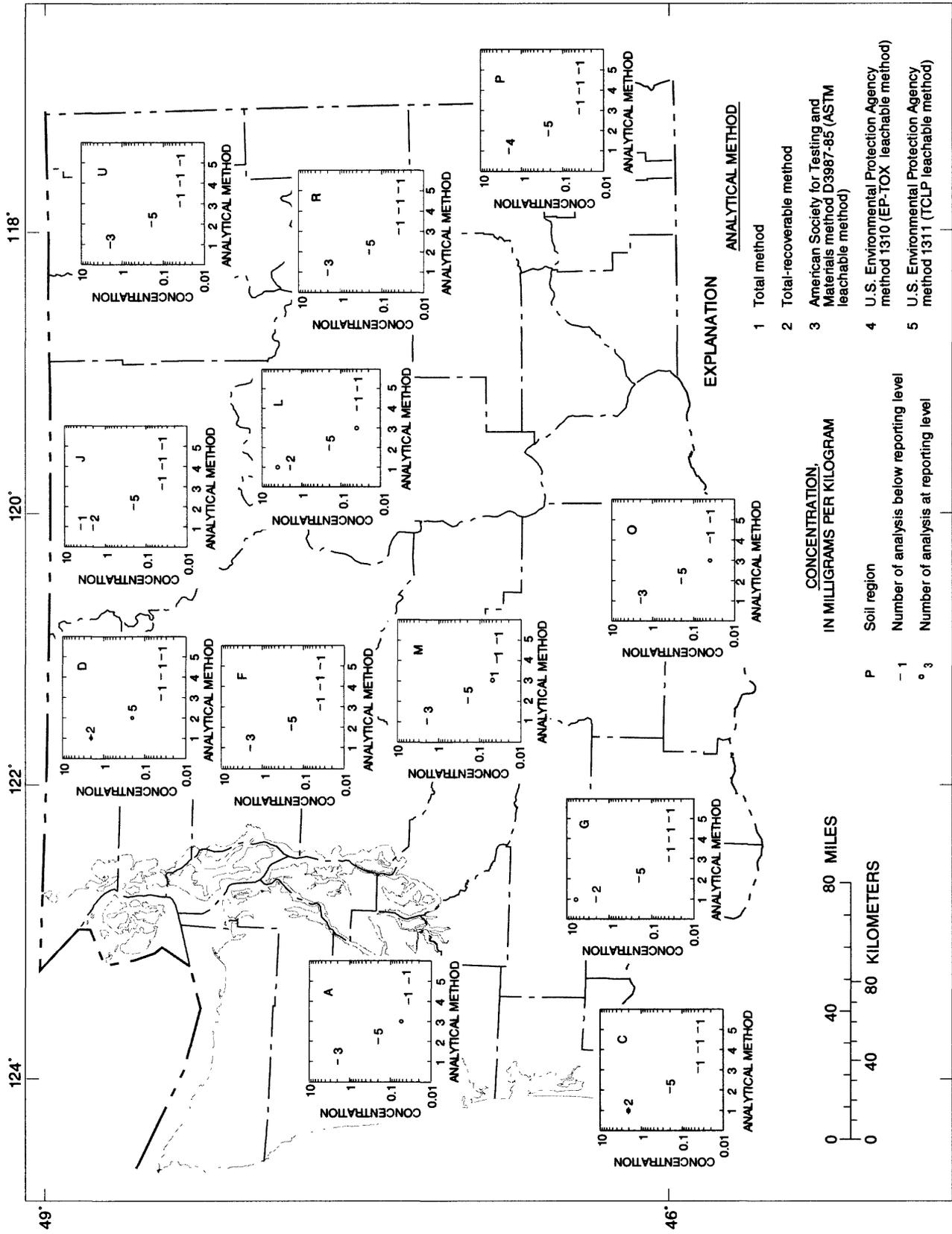


Figure 9.--State of Washington, county boundaries, and concentrations of cadmium determined by 5 analytical methods for 12 soil regions.

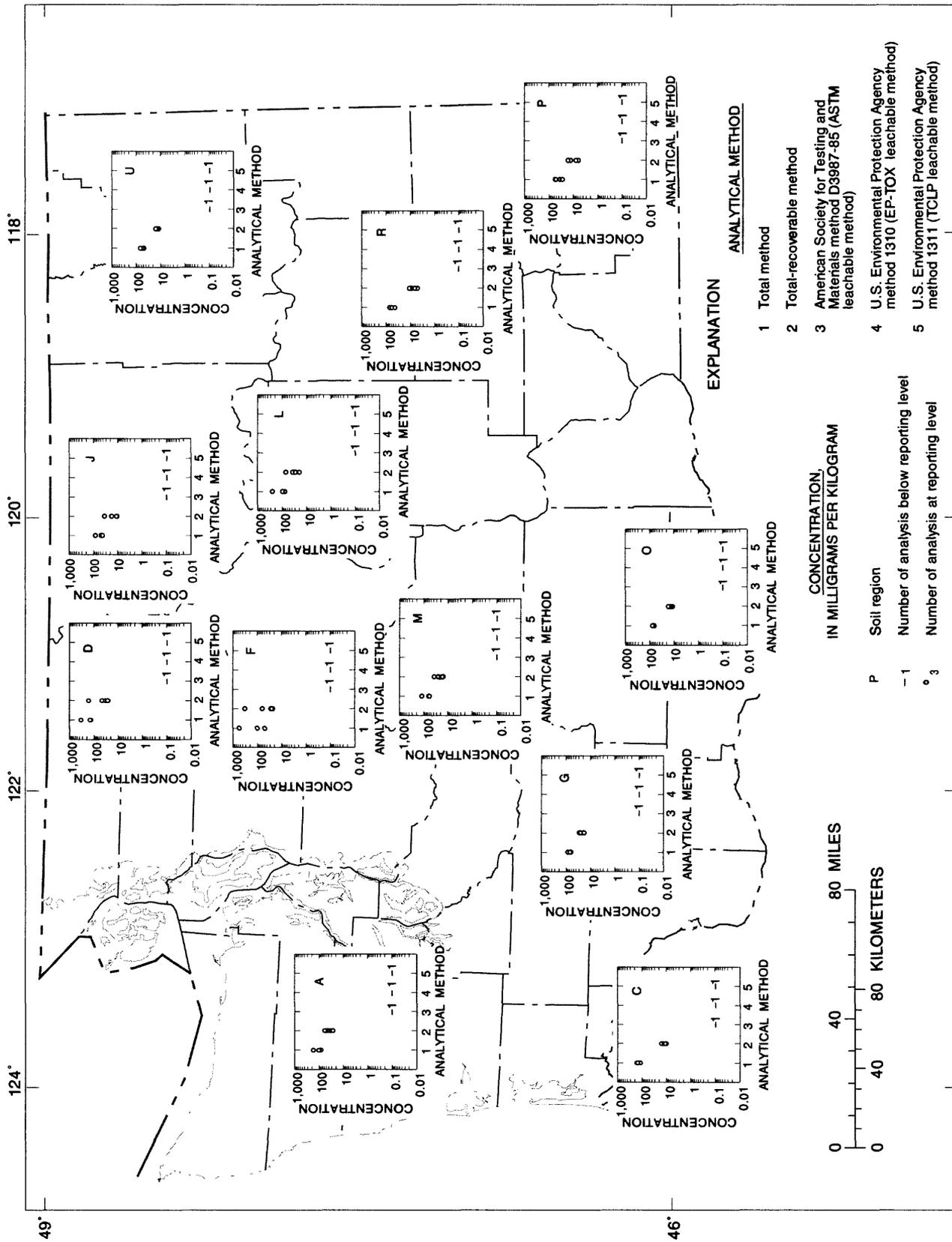


Figure 10.--State of Washington, county boundaries, and concentrations of chromium determined by 5 analytical methods for 12 soil regions.

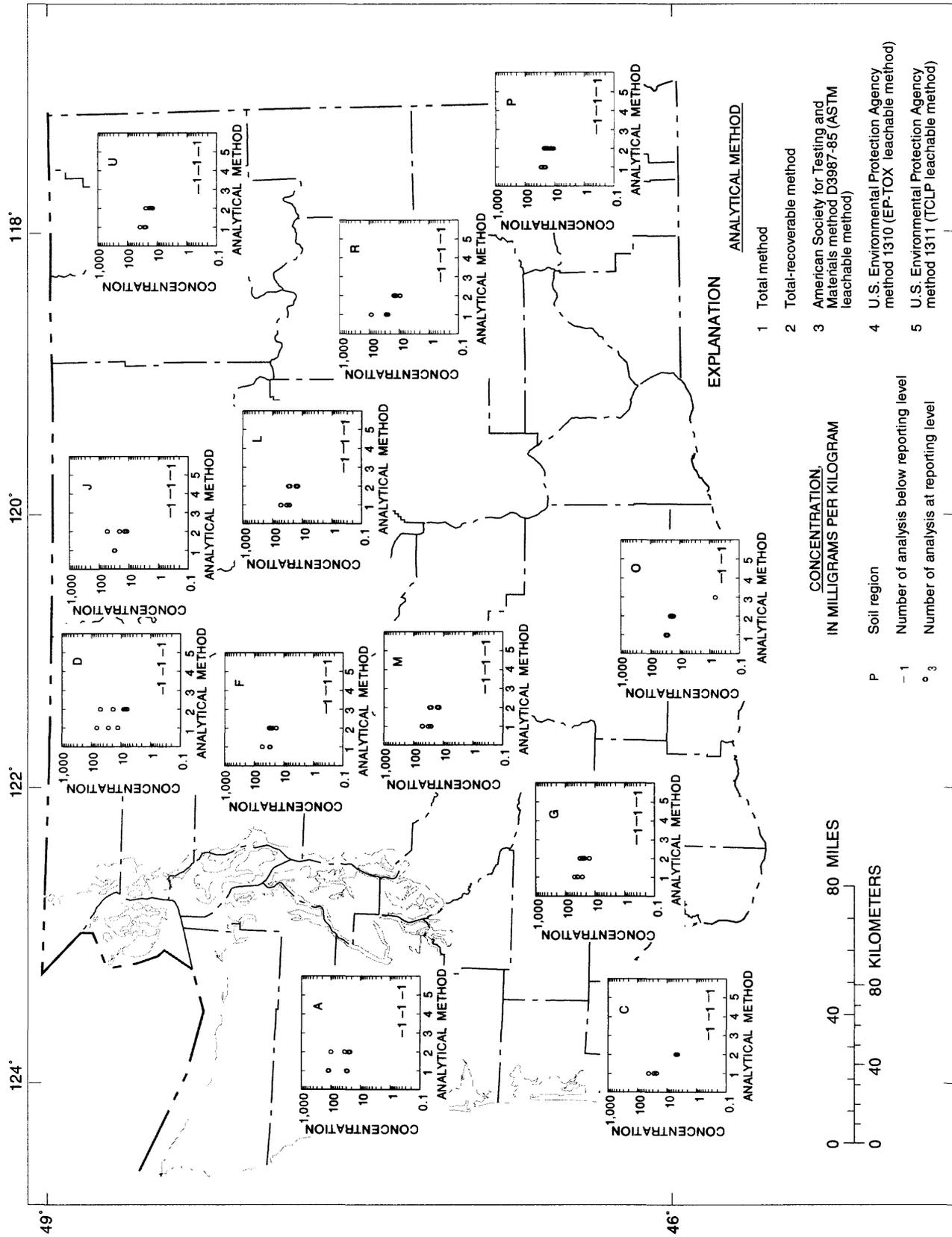


Figure 11.--State of Washington, county boundaries, and concentrations of copper determined by 5 analytical methods for 12 soil regions.

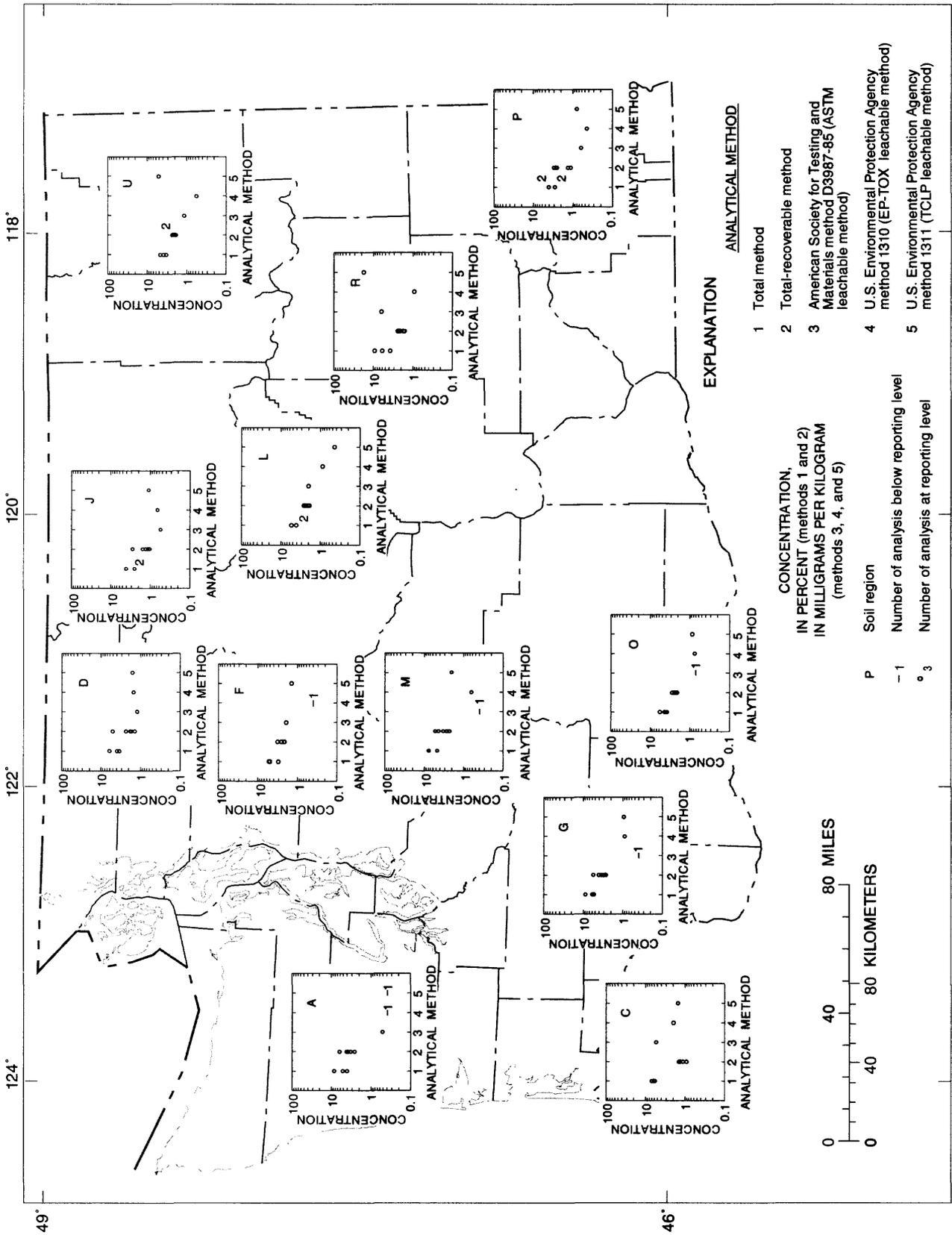


Figure 12.--State of Washington, county boundaries, and concentrations of iron determined by 5 analytical methods for 12 soil regions.

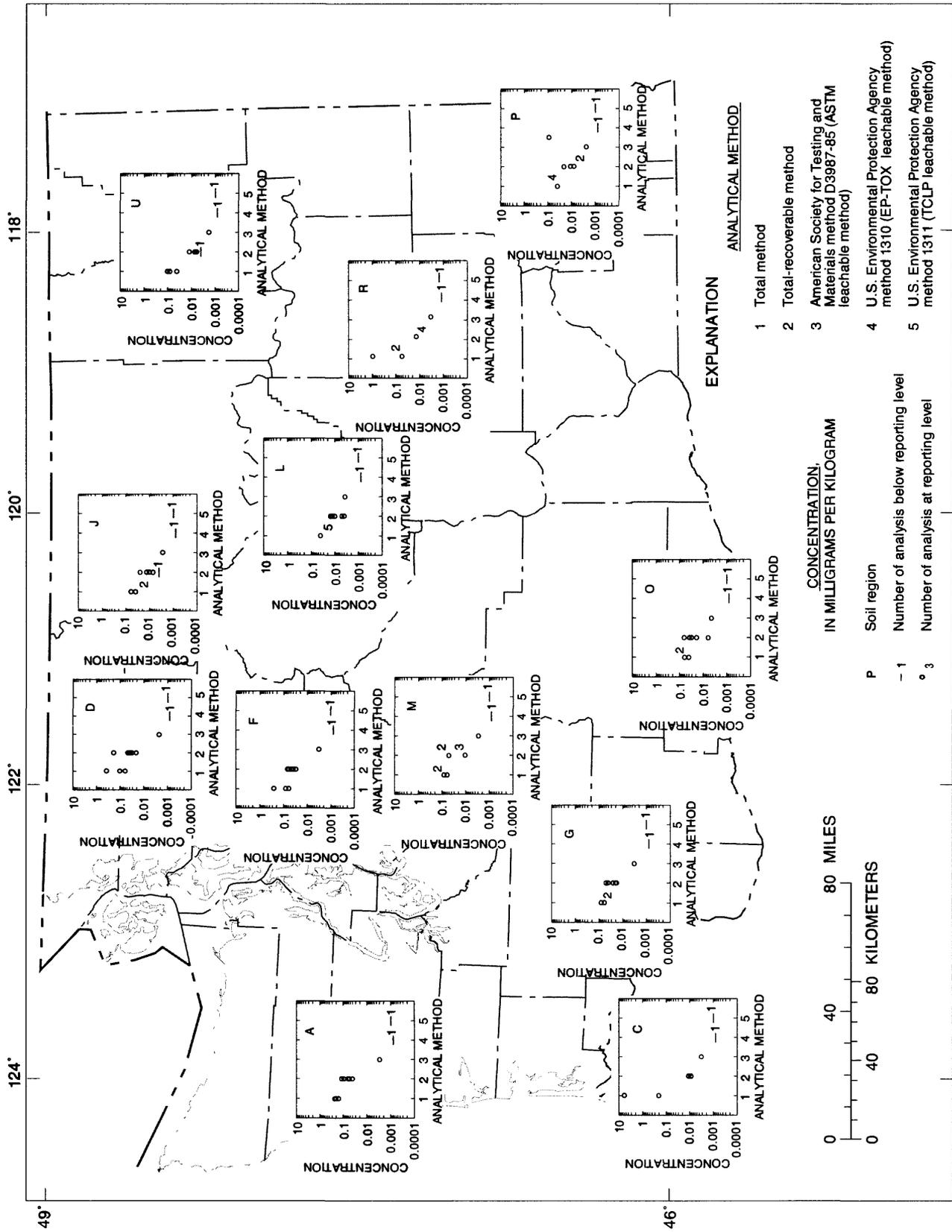


Figure 13.--State of Washington, county boundaries, and concentrations of mercury determined by 5 analytical methods for 12 soil regions.

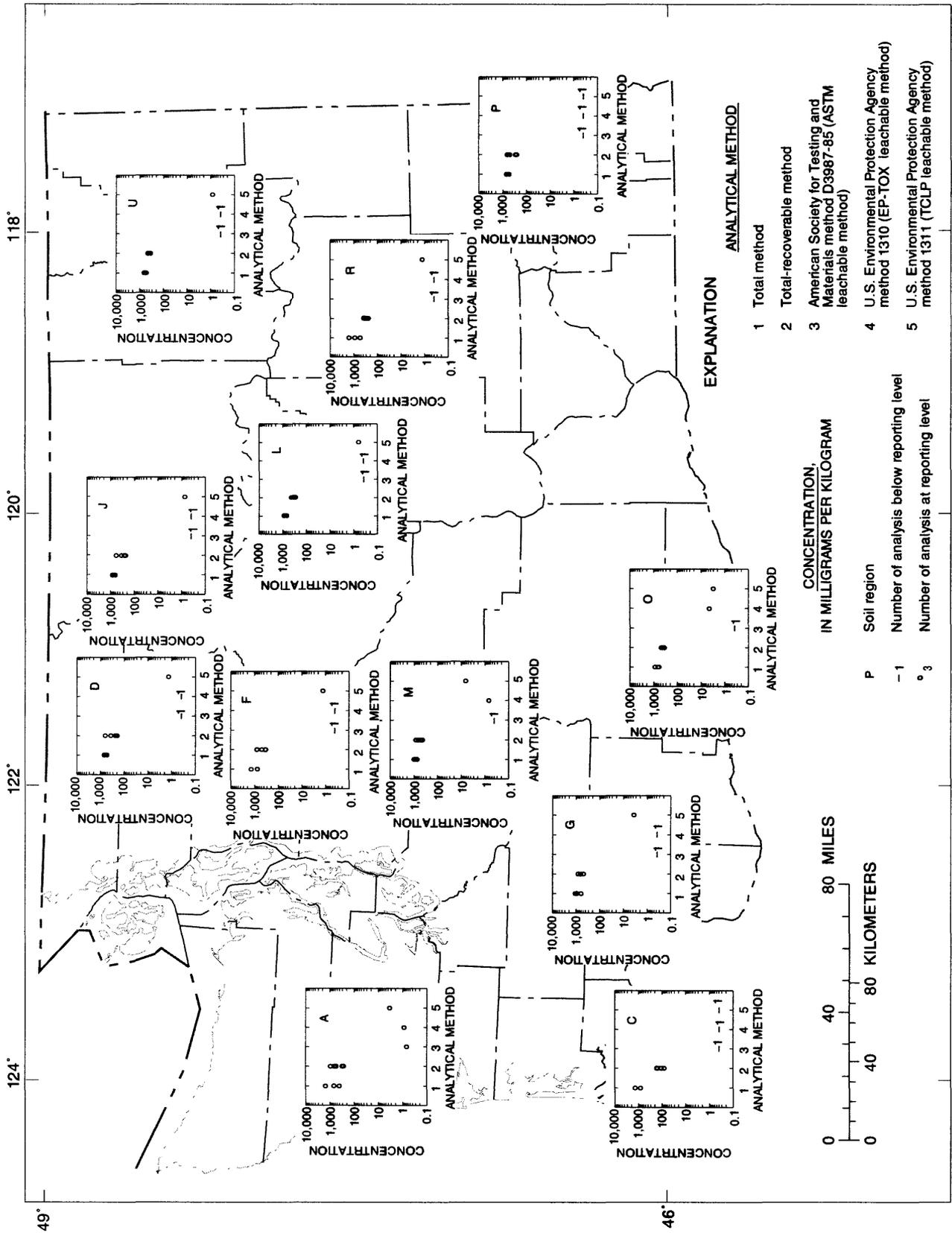


Figure 14.--State of Washington, county boundaries, and concentrations of manganese determined by 5 analytical methods for 12 soil regions.

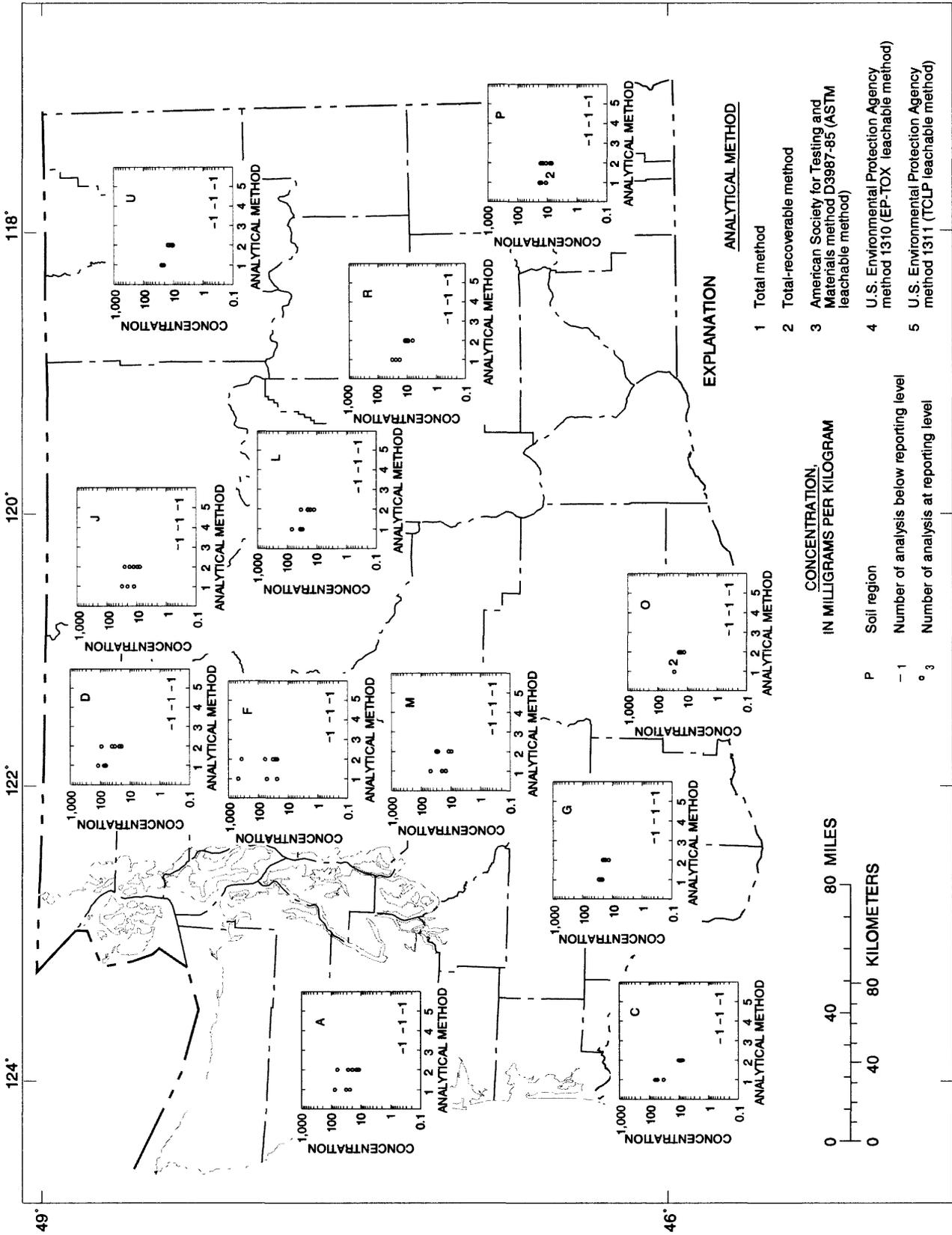


Figure 15.--State of Washington, county boundaries, and concentrations of nickel determined by 5 analytical methods for 12 soil regions.

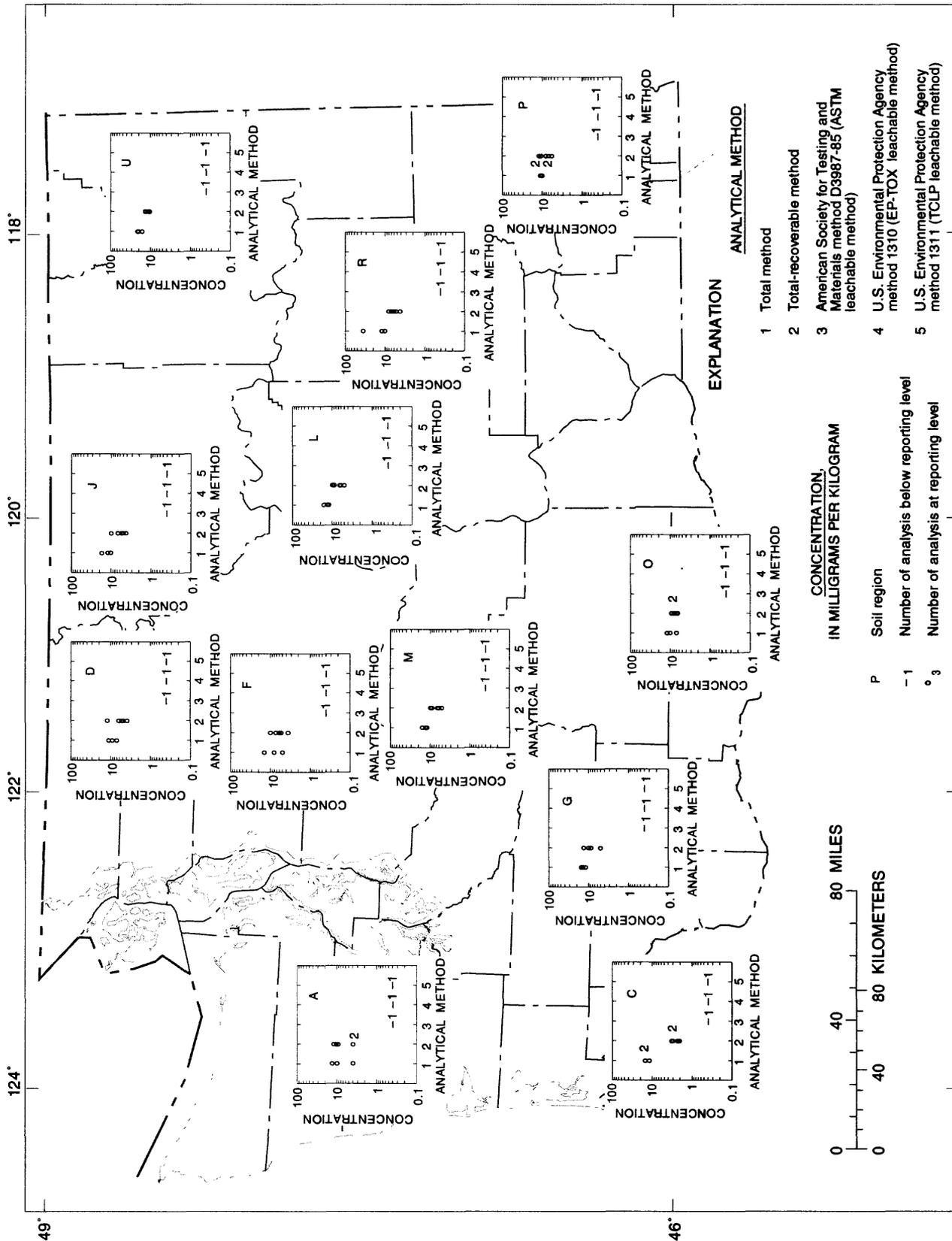


Figure 16.--State of Washington, county boundaries, and concentrations of lead determined by 5 analytical methods for 12 soil regions.

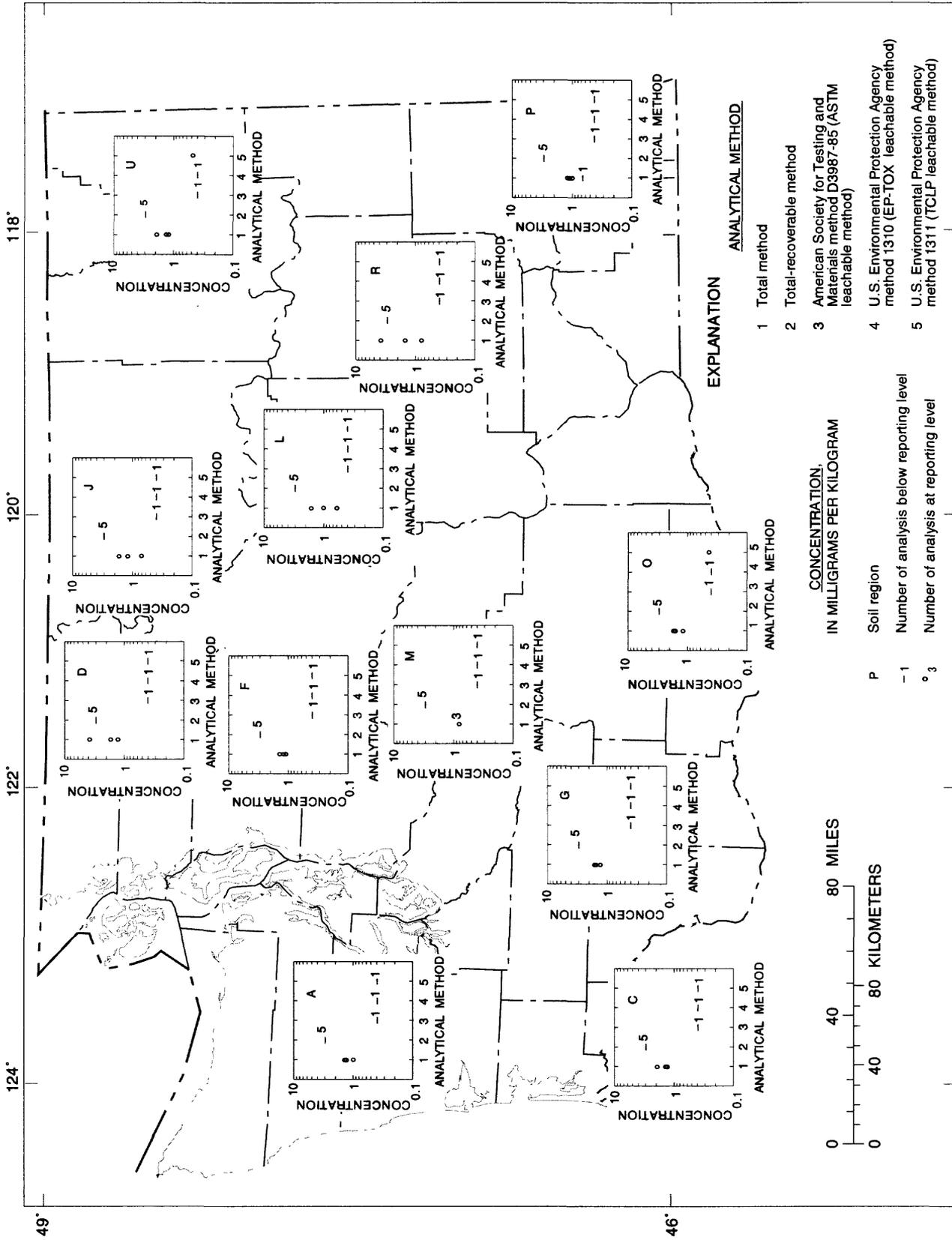


Figure 17.--State of Washington, county boundaries, and concentrations of antimony determined by 5 analytical methods for 12 soil regions.

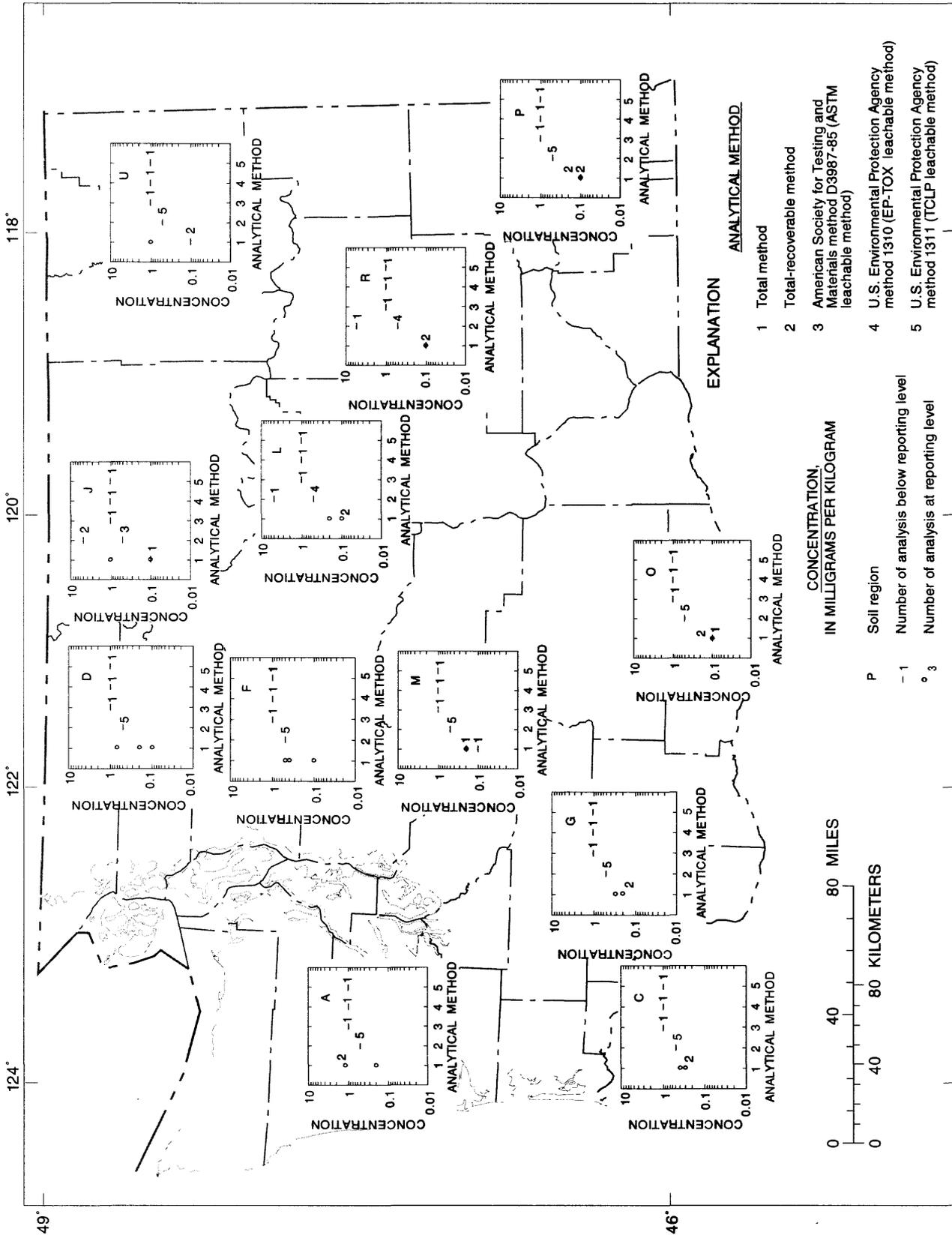


Figure 18 --State of Washington, county boundaries, and concentrations of selenium determined by 5 analytical methods for 12 soil regions.

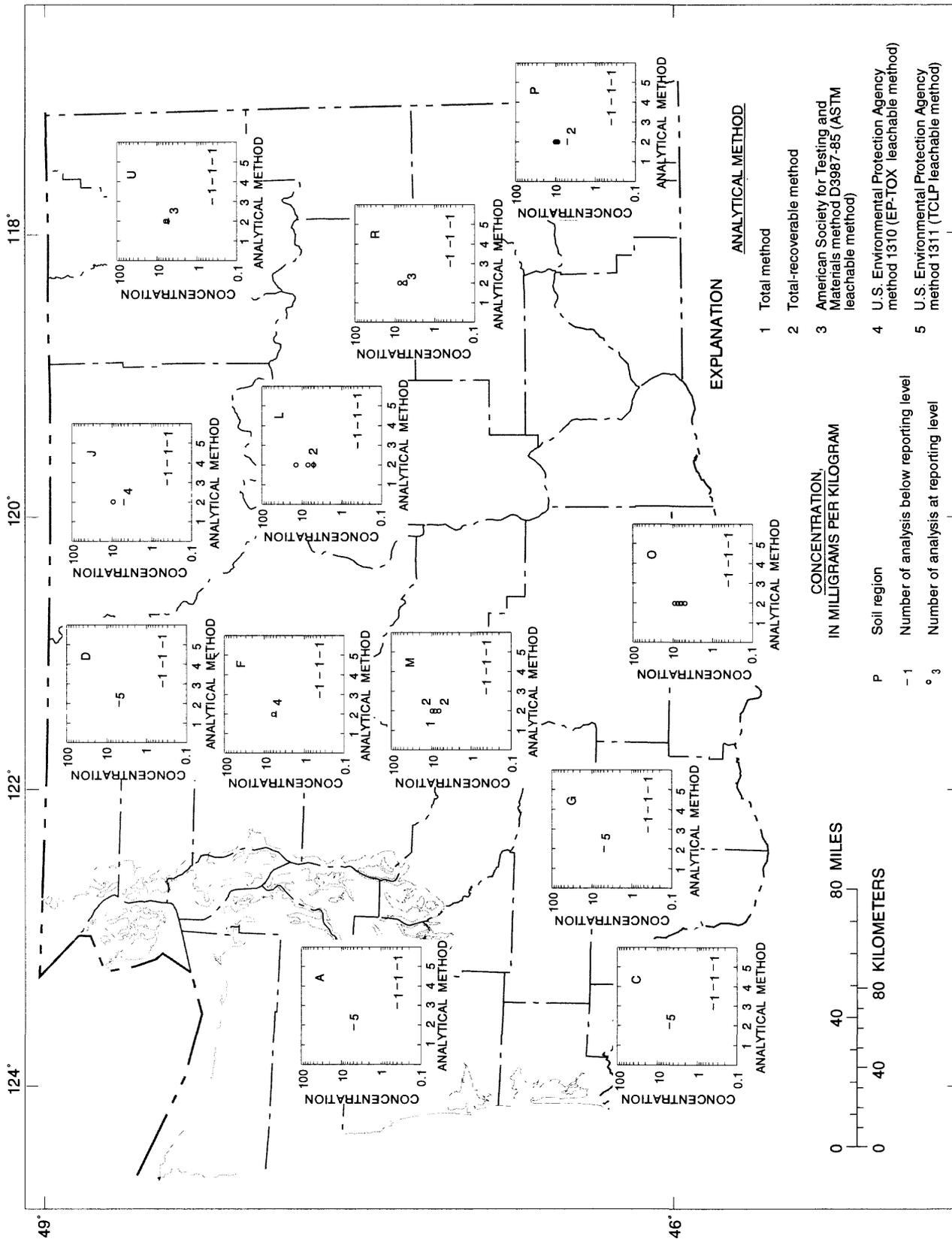


Figure 19 --State of Washington, county boundaries, and concentrations of thallium determined by 5 analytical methods for 12 soil regions.

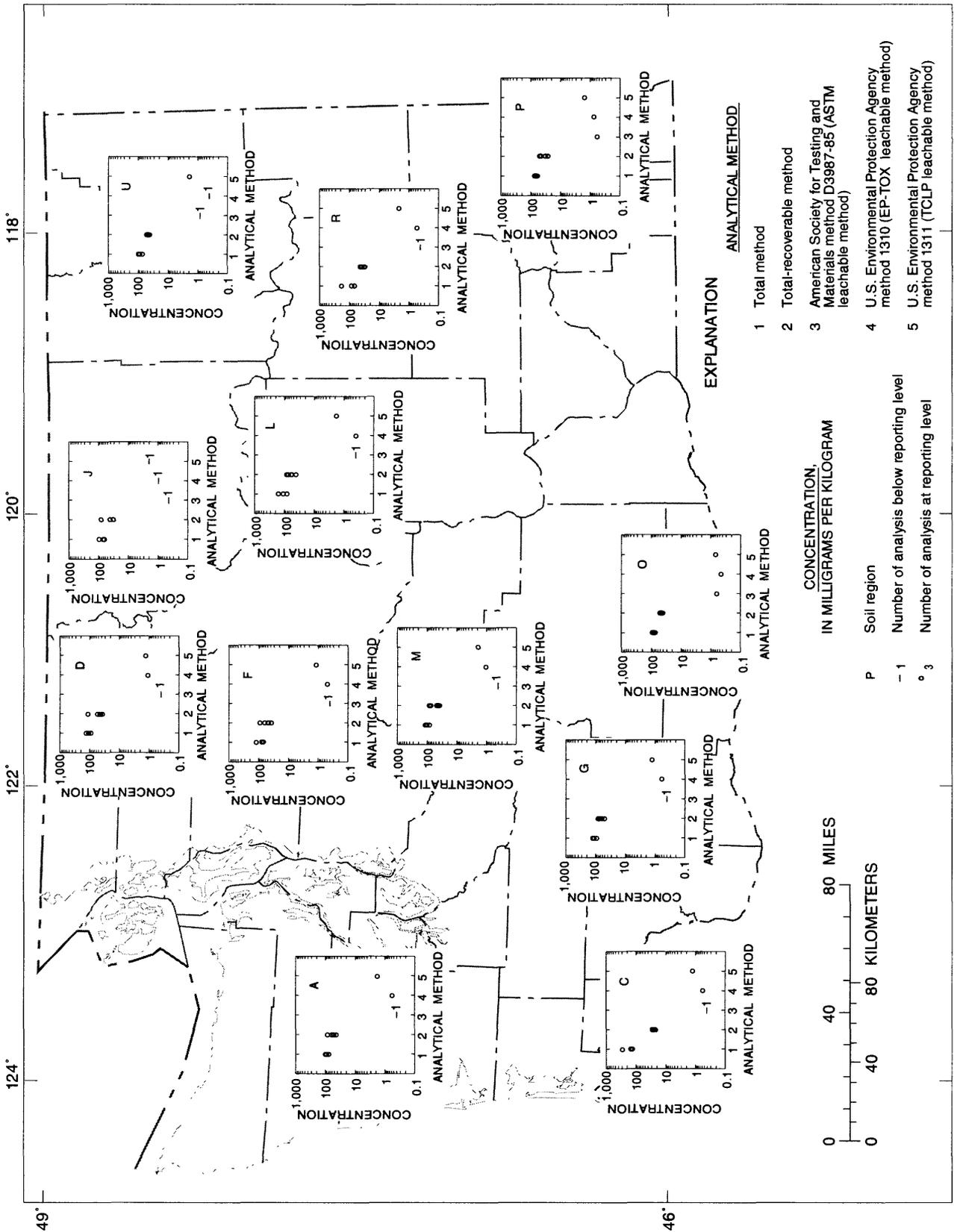


Figure 20.--State of Washington, county boundaries, and concentrations of zinc determined by 5 analytical methods for 12 soil regions.

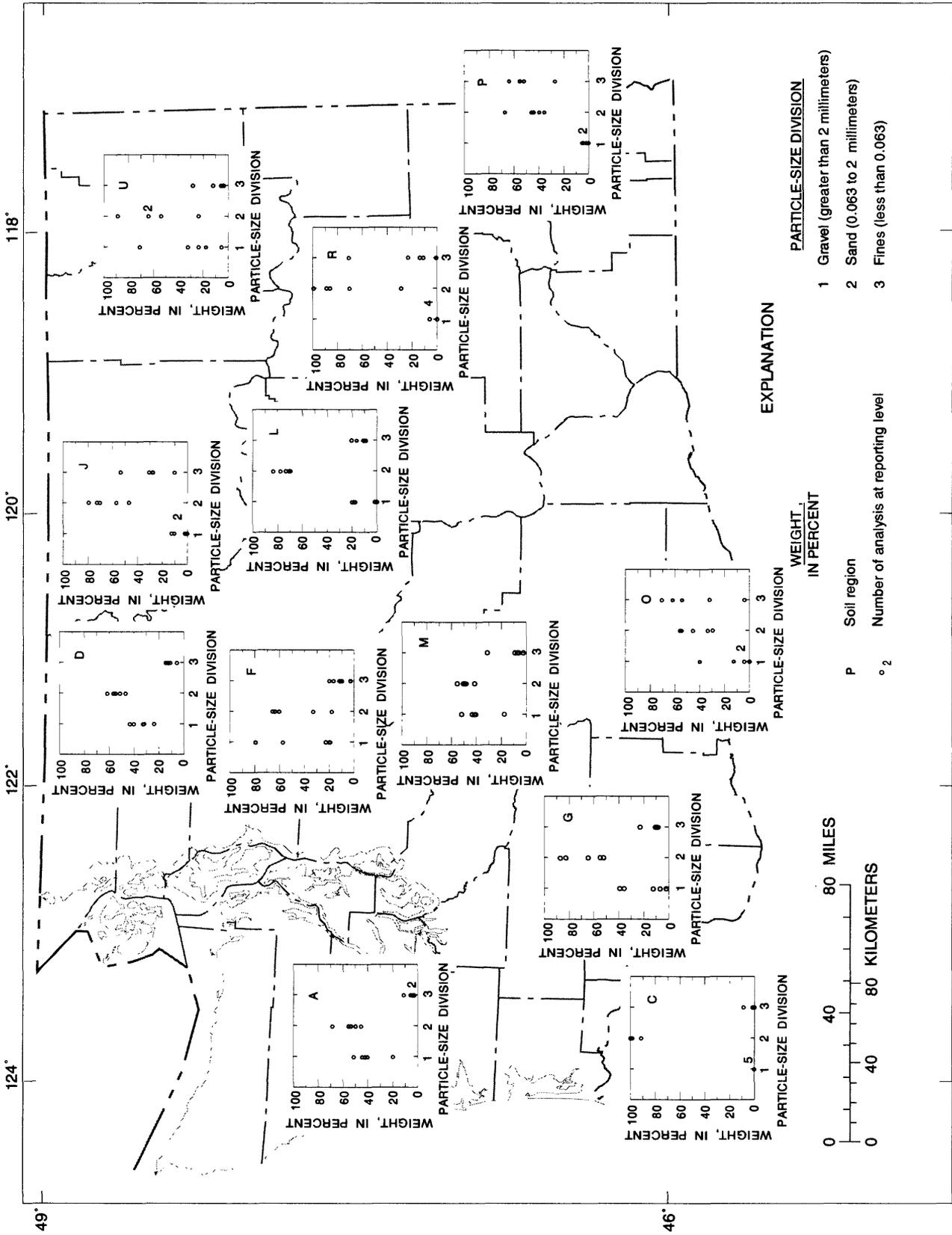


Figure 21.--State of Washington, county boundaries, and particle-size distributions determined for 12 soil regions.

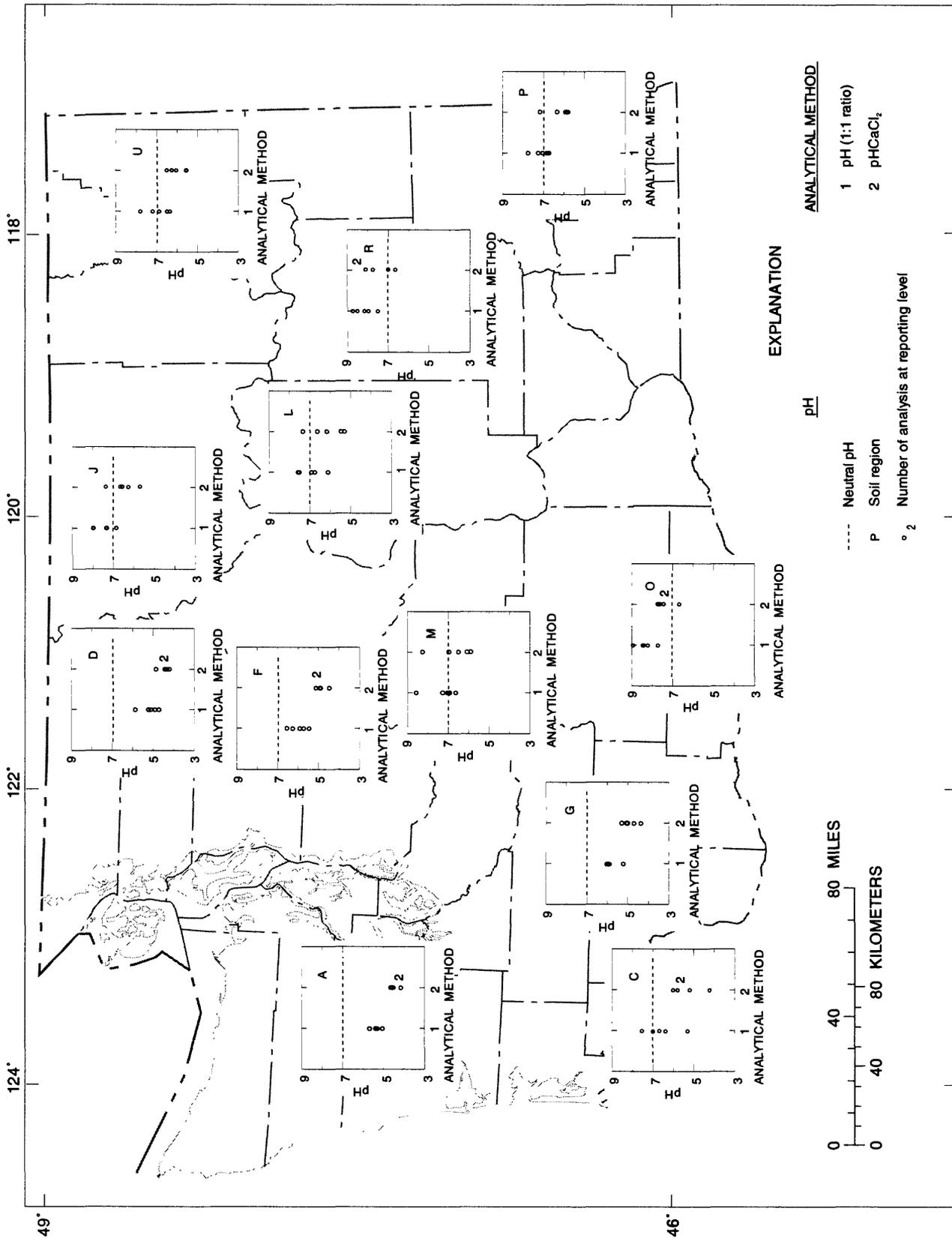


Figure 22.--State of Washington, county boundaries, and soil-solution pH determined by 2 analytical methods for 12 soil regions.

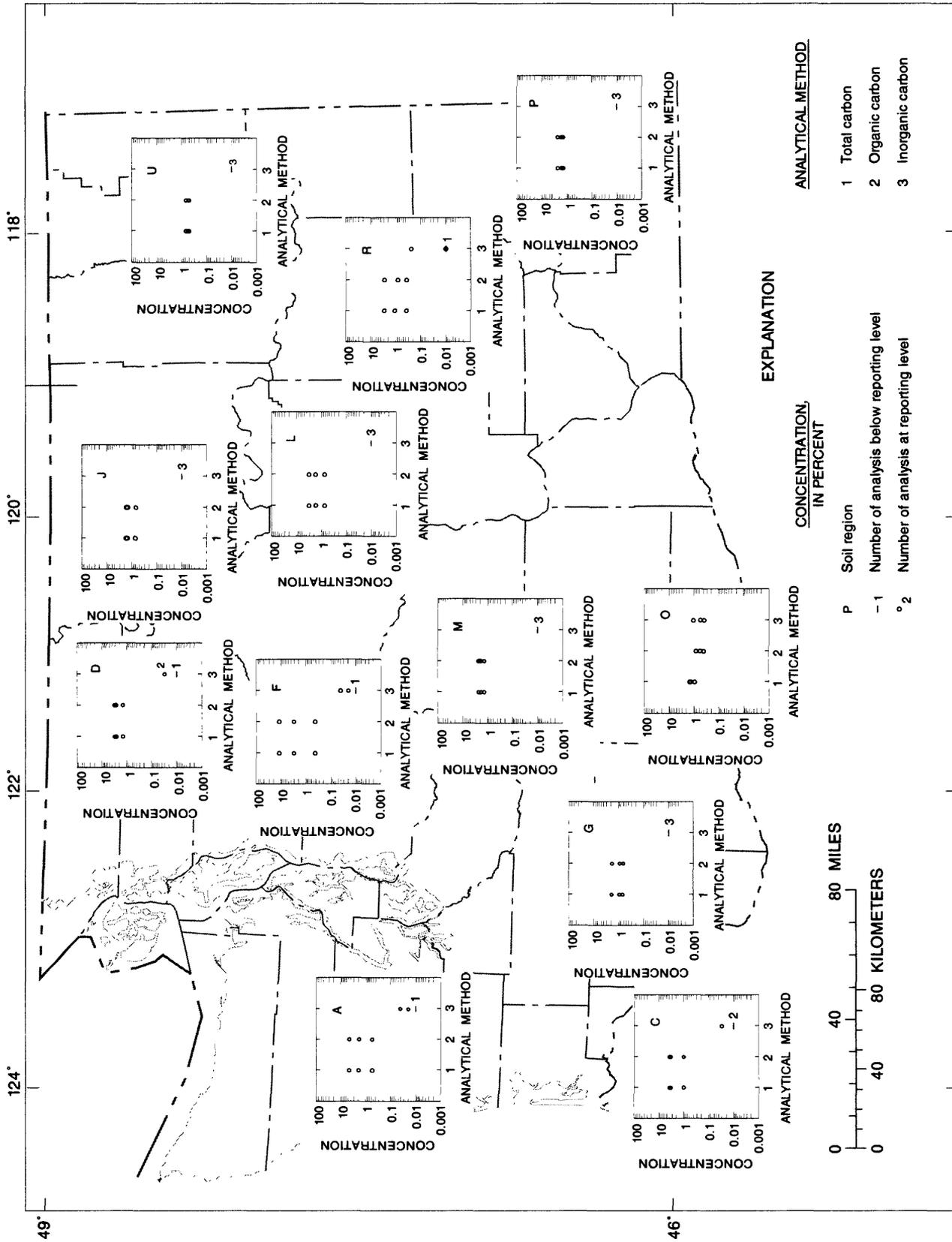


Figure 23.--State of Washington, county boundaries, and carbon content determined for 12 soil regions.

Table 9.--Frequency distributions of metals concentrations in soils in Washington determined by the total and total-recoverable methods

[N and L indicate that the null hypotheses that the data are distributed normally or log-normally could not be rejected at a 95 percent confidence level; (L) indicates that the null hypothesis could be rejected but the correlation coefficients and graphical inspection of the plots demonstrate that the distributions are more nearly log-normal than normal; O indicates that both null hypotheses could be rejected; -- signifies that hypothesis was not tested because concentrations were not determined or too many were less than the laboratory's minimum reporting level]

Metal	Total method		Total-recoverable method	
	Distribution	Total number of samples/detects ¹	Distribution	Total number of samples/detects ¹
Ag	--	37/0	--	60/12
Al	L	37/37	L	60/60
As	L	37/37	L	60/59
Au	--	37/0	--	0/0
Ba	N	37/37	--	0/0
Be	--	37/34	N	60/60
Bi	--	37/0	--	0/0
Ca	L	37/37	--	0/0
Cd	--	37/4	--	60/0
Ce	O	37/37	--	0/0
Co	L	37/37	--	0/0
Cr	(L)	37/37	(L)	60/60
Cu	(L)	37/37	(L)	60/60
Eu	--	37/3	--	0/0
Fe	L	37/37	L	60/60
Ga	N	37/37	--	0/0
Hg	(L)	37/37	L	60/52
Ho	--	37/0	--	0/0
K	N	37/37	--	0/0
La	L	37/37	--	0/0
Li	(L)	37/37	--	0/0
Mg	L	37/37	--	0/0
Mn	L	37/37	N	60/60
Mo	--	37/7	--	0/0
Na	(L)	37/37	--	0/0
Nb	O	37/36	--	0/0
Nd	L	37/37	--	0/0
Ni	(L)	37/37	(L)	60/60
P	(L)	37/37	--	0/0
Pb	(L)	37/37	N	60/60

Table 9.--Frequency distributions of metals concentrations in soils in Washington determined by the total and total-recoverable methods--Continued

Metal	Total method		Total-recoverable method	
	Distribution	Total number of samples/ detects ¹	Distribution	Total number of samples/ detects ¹
Sb	(L)	37/36	--	60/0
Se	(L)	37/29	--	60/0
Sc	L	37/37	--	0/0
Sn	--	37/0	--	0/0
Sr	N	37/37	--	0/0
Ta	--	37/0	--	0/0
Th	O	37/36	--	0/0
Tl	--	0/0	--	60/21
Ti	L	37/37	--	0/0
U	--	37/0	--	0/0
V	L	37/37	--	0/0
Y	L	37/37	--	0/0
Yb	(L)	37/37	--	0/0
Zn	(L)	37/37	L	60/60

¹ Detects are the number of samples with concentrations greater than laboratory minimum reporting level.

Comparison of Metal Concentrations Among Regions

Concentrations of metals in the various regions were compared to determine whether the regions are different from one another or whether data in individual regions are sufficiently similar so that regions can be grouped. If the metals concentrations in the individual regions are statistically different from one another, then sets of data should probably be developed and statistically analyzed separately for each region to define baseline concentrations. If not, then data sets from different regions could be grouped and statistically analyzed to define baseline concentrations, if geology and pedology support making such groups.

Kruskal-Wallis Test

The Kruskal-Wallis test, which is a non-parametric one-way analysis of variance (see, for example, Iman and Conover, 1983), was used to compare the mean ranks of metal concentrations determined by the total and total-recoverable methods in a region with the corresponding mean ranks in other regions (at a 95 percent confidence level). The test was performed separately for each metal. The null hypothesis, that the population means of metals concentrations in each of the 12 regions were equal with one another, was rejected for all metals tested, except total copper and manganese. However, this does not imply that the population means of all metals tested for each region are different from one another, nor does it indicate where differences are located.

Fisher's Least Significant Difference Test

To determine where differences are located among the 12 population means for each metal, the Fisher's Least Significant Difference test was used (Iman and Conover, 1983). A test statistic was calculated for each metal from the values generated by the analysis of variance of the ranks. The mean ranks of the 12 regions were then compared, and the test statistic was used to determine whether the mean ranks, and therefore the concentrations of metals in the regions, were similar (at a 95 percent confidence level) (table 10). For illustrative purposes, table 10 shows a comparison of concentrations of metals in region A with those in the other regions, in which concentrations of metals are not significantly different from those in region A (underlined values). The concentrations of metals determined by the total method in region A are similar to concentrations in all other regions, with the possible exception of regions J and U, where 4 of 11 metals did not compare well, and region P, where 7 of 11 metals did not compare well. Concentrations of arsenic, copper, and manganese for region A are similar to concentrations in each of the 11 other regions, and concentrations of lead and zinc are similar to concentrations in 9 of the 11 other regions.

The total-recoverable metals concentrations are not as similar among regions as the total metals concentrations (table 10). Only concentrations of total-recoverable arsenic and lead in region A are similar to concentrations among other regions. The concentrations of total-recoverable arsenic and lead for region A compare well with concentrations from 10 of the 11 other regions. Concentrations of all metals in region A are similar to concentrations in region F and to concentrations of 8 of 11 metals in regions G and L. The association between regions A and F is particularly strong and may result from the similar nature of the parent material from which these soils were derived and the similar climatic environment in which these soils were developed.

A comparison of differences between the mean ranks of metals for regions O, P, and R with the test statistic indicates that concentrations of metals in these regions are similar at least to one other. For example, the rank means for total-recoverable beryllium of region O and region P are not statistically different; likewise, the rank means between region O and region R are not statistically different; however, the rank means between regions P and R are statistically different. The three regions are located adjacent to one another and are composed primarily of soils that developed in fine wind blown sediments under fairly similar climatic conditions.

Cluster Analysis

Cluster analyses (see, for example, Kaufman and Rousseeuw, 1990; and Romesburg, 1984) of total and total-recoverable metals concentrations were also performed so that data could be placed into distinct groups without presupposition of existent regions. This analysis was also performed with ranks of the data. Cluster analysis is designed to classify data by assigning observations into more or less homogeneous groups that are distinct from other groups. Well-separated cases of the data were chosen as cluster centers to which individual sites were assigned to form distinct cluster groups.

Cluster analyses indicate that samples collected from regions A and F and sites 4 and 5 from region D may be combined into two distinct groups. One group consists of sites that are located in an inner ring encompassing Puget Sound (sites F3, F5, A2, A4, and D4). The remaining sites, of regions A and F and site 5 from region D, compose the other cluster group, which forms an outer ring in the Puget Sound uplands.

Cluster analyses also indicate that samples from regions O, P, and R may be placed into two distinct groups. One cluster group consists of sites located in the southern extent of region R and the southwestern extent of region P (sites R1, R3, R4, R5, P4, and P5). The other cluster group consists of all sites located in region O and the remaining sites in regions P and R (sites O1, O2, O3, O4, O5, P1, P2, P3, and R2).

Relations Among Metal Concentrations

Correlation coefficients and regression statistics between total-recoverable and total metal concentrations were calculated for those metals for which concentrations were determined by both methods and for which concentrations were greater than the laboratory's minimum reporting level. The Spearman ranked correlation coefficients for 11 metals ranged from 4 to 70 percent (table 11). For 7 of the 11 metals tested, total-recoverable metals concentrations correlated with the total metal concentrations in the soil at a 95 percent confidence level. For the remaining metals, the total and total-recoverable concentrations were statistically independent of one another. Pearson correlation coefficients were calculated from non-transformed data for the seven metals that displayed significant Spearman ranked correlation coefficients. The Pearson correlation coefficients ranged from 41 to 98 percent and confirmed that for all of the seven metals tested, including aluminum, arsenic, copper, chromium, iron,

Table 10.--Mean ranks of total and total-recoverable concentrations of selected metals in different soil regions in Washington

[Values in parentheses are test statistics determined from an analysis of variance of the ranks, and underlined ranks are not statistically different at the 95 percent confidence level from mean ranks for region A; n, number of samples used for statistical calculation]

Mean ranks of concentrations from total method by soil region, n = 37												
Metal	A	C	D	F	G	J	L	M	O	P	R	U
Al (13.2)	<u>25.8</u>	<u>14.7</u>	<u>30.8</u>	<u>21.8</u>	<u>27.3</u>	12.2	<u>30.5</u>	<u>23.5</u>	11.8	8.8	4.7	<u>19.5</u>
As (15.1)	<u>19.0</u>	<u>34.0</u>	<u>24.5</u>	<u>16.7</u>	<u>23.5</u>	8.0	<u>16.3</u>	<u>4.8</u>	<u>21.5</u>	<u>14.8</u>	<u>18.2</u>	<u>28.2</u>
Be (12.5)	9.0	<u>15.2</u>	9.0	<u>15.2</u>	<u>21.3</u>	<u>21.3</u>	27.5	9.0	27.5	22.9	<u>21.3</u>	27.5
Cr (12.5)	<u>28.0</u>	<u>31.2</u>	<u>32.3</u>	<u>23.2</u>	<u>17.0</u>	10.8	<u>27.0</u>	<u>18.3</u>	<u>17.3</u>	5.4	10.0	12.0
Cu (18.3) ¹	<u>24.2</u>	<u>14.7</u>	<u>17.2</u>	<u>25.7</u>	<u>23.8</u>	<u>24.3</u>	<u>25.3</u>	<u>20.7</u>	<u>18.0</u>	<u>7.9</u>	<u>16.3</u>	<u>13.7</u>
Fe (14.2)	<u>24.5</u>	<u>30.3</u>	<u>15.8</u>	<u>16.2</u>	<u>29.0</u>	6.2	<u>18.5</u>	<u>28.8</u>	<u>17.7</u>	8.0	<u>25.2</u>	<u>11.5</u>
Hg (11.8)	<u>30.5</u>	<u>34.5</u>	<u>26.3</u>	<u>24.8</u>	<u>19.7</u>	10.5	7.0	<u>21.8</u>	14.0	7.0	16.3	<u>19.5</u>
Mn (16.5) ¹	<u>18.0</u>	<u>29.0</u>	<u>10.2</u>	<u>26.2</u>	<u>24.7</u>	<u>16.7</u>	<u>21.3</u>	<u>26.5</u>	<u>16.5</u>	<u>11.0</u>	<u>23.7</u>	<u>7.0</u>
Ni (12.0)	<u>25.3</u>	<u>29.0</u>	<u>34.0</u>	<u>26.5</u>	<u>14.7</u>	11.5	<u>27.5</u>	<u>13.7</u>	<u>19.8</u>	3.6	<u>15.5</u>	12.0
Pb (14.4)	<u>11.3</u>	26.2	8.0	<u>11.0</u>	<u>25.0</u>	<u>21.0</u>	<u>25.2</u>	<u>10.8</u>	<u>23.3</u>	<u>12.0</u>	<u>22.0</u>	34.5
Zn (14.1)	<u>20.0</u>	34.3	<u>26.0</u>	<u>15.7</u>	<u>27.5</u>	9.3	<u>25.7</u>	<u>21.7</u>	<u>12.3</u>	5.5	<u>18.7</u>	<u>15.8</u>

Mean ranks of concentrations from total-recoverable method by soil region, n = 60												
Metal	A	C	D	F	G	J	L	M	O	P	R	U
Al (9.8)	<u>55.4</u>	4.0	38.4	<u>49.0</u>	45.0	16.6	40.9	38.3	17.4	28.8	8.0	24.2
As ² (19.2)	<u>34.4</u>	<u>23.3</u>	<u>35.9</u>	<u>27.5</u>	<u>36.2</u>	<u>20.3</u>	<u>22.6</u>	<u>16.2</u>	<u>42.2</u>	<u>25.7</u>	<u>31.0</u>	55.0
Be (15.4)	<u>36.5</u>	3.0	<u>22.0</u>	<u>33.0</u>	<u>45.1</u>	17.6	<u>41.5</u>	52.4	<u>32.0</u>	<u>39.3</u>	14.8	<u>28.8</u>
Cr (11.6)	<u>50.6</u>	14.9	<u>48.7</u>	<u>47.1</u>	36.7	26.1	<u>48.0</u>	35.2	19.9	13.9	4.7	20.2
Cu (15.9)	<u>49.3</u>	3.0	22.0	<u>47.0</u>	<u>43.3</u>	26.8	<u>34.7</u>	<u>41.8</u>	32.9	24.3	14.5	26.4
Fe (15.2)	<u>51.7</u>	5.7	25.9	<u>37.2</u>	<u>51.0</u>	14.4	29.4	<u>47.0</u>	31.3	26.8	22.6	23.0
Hg ³ (13.2)	<u>54.4</u>	22.2	<u>46.0</u>	<u>49.0</u>	40.7	26.4	19.9	33.6	37.3	26.5	22.0	16.9
Mn (16.8)	<u>38.4</u>	3.0	19.8	<u>39.2</u>	<u>50.3</u>	21.0	<u>26.2</u>	<u>47.4</u>	<u>33.0</u>	<u>34.8</u>	21.4	<u>31.5</u>
Ni (14.4)	<u>39.6</u>	8.3	<u>50.2</u>	<u>53.0</u>	<u>37.1</u>	23.7	<u>38.7</u>	<u>36.5</u>	<u>31.4</u>	16.1	11.2	20.2
Pb (17.4)	<u>33.5</u>	3.0	<u>23.2</u>	<u>25.5</u>	<u>39.5</u>	<u>23.0</u>	<u>29.1</u>	<u>34.8</u>	<u>39.1</u>	<u>37.5</u>	<u>22.8</u>	<u>55.0</u>
Zn (16.3)	<u>45.1</u>	3.2	<u>34.3</u>	<u>38.0</u>	<u>49.5</u>	21.2	<u>44.2</u>	<u>33.2</u>	25.1	23.4	15.0	<u>33.8</u>

¹ Test statistic probability of error greater than 10 percent.

² n = 59; values below reporting limit not used in calculations of mean rank or test statistic.

³ n = 52; values below reporting limit not used in calculations of mean rank or test statistic.

Table 11.--Correlation coefficients and regression statistics between total-recoverable concentrations and total concentrations of selected metals in soils in Washington

[R_s, Spearman ranked correlation coefficient; R_p, Pearson correlation coefficient for goodness of fit for the regression equations; a, regression coefficient (slope); b, regression coefficient (intercept); total-recoverable concentration = a x (total concentration) + b; ratio, total:total-recoverable; underlined values demonstrate a significant correlation at a 95 percent confidence level; -- indicates no value calculated]

Element	R _s	R _p	a	b	Ratio	
					Mean	Standard deviation
Ag	--	--	--	--	--	--
Al	<u>.68</u>	<u>.71</u>	0.87	-4.9	0.27	0.14
As	<u>.56</u>	<u>.46</u>	.27	2	.59	.25
Be	4	--	--	--	.42	.29
Ce	--	--	--	--	--	--
Cu	<u>.58</u>	<u>.77</u>	.62	-.8	.60	.21
Cr	<u>.70</u>	<u>.94</u>	.53	-22	.28	.11
Fe	<u>.51</u>	<u>.61</u>	.47	.4	.53	.17
Hg ¹	<u>.58</u>	<u>.41</u>	.12	2	.32	.23
Mn	27	--	--	--	.58	.23
Ni	<u>.65</u>	<u>.98</u>	.76	-7	.58	.22
Pb	23	--	--	--	.66	.31
Sb	--	--	--	--	--	--
Se	--	--	--	--	--	--
Zn	29	--	--	--	.55	.19

Example: If total aluminum = 7.3 percent, then the estimated total-recoverable aluminum concentration equals (0.87 X 7.3 percent) - 4.9 percent = 1.5 percent.

¹ Values for mercury do not include data for samples collected from region C.

mercury, and nickel, total-recoverable concentrations correlated with total metal concentrations at a 95 percent confidence level. Therefore, the amount of these metals that may ultimately be bioavailable is dependent upon total concentrations in the silt and clay fractions of the soil. A poor correlation between the total-recoverable and total metals concentrations of beryllium, manganese, lead, and zinc suggests that the form in which the metal was held--within the mineral matrices, on various exchanger sites, or in poorly crystalline to amorphous compounds--varied among samples.

A dilution factor for silt- and clay-sized particles in streambed sediments, described by Horowitz (1991), was used to correct for particle-size differences between the metals concentrations determined by the total method and those determined by the total-recoverable method.

Spearman ranked correlation coefficients were calculated for the corrected total metals concentrations and the total-recoverable metals concentrations (not shown). For all 11 metals tested, the correlation coefficients calculated for the corrected total metals concentrations were less than those calculated for the non-corrected total metals concentrations. This suggests that the bioavailability of metals in soils does not depend upon the total metals concentrations in coarser (sand) sized particles.

Table 11 also lists regression equation constants for the same seven metals, as well as means and standard deviations of the total-recoverable to total ratios for each metal. The mean ratios range from 0.27 to 0.66, and there are apparently no relations between the correlation coefficients and the mean ratios. The ratios between total-recoverable and total values (not shown) also vary from

region to region. For example, in region C, the ratios for both manganese and zinc approach 0, whereas in region F, ratio values more nearly approach 1.0. Low total-recoverable to total ratios suggest that most of the metal is held within the mineral matrix and is only removed when hydrofluoric acid is used during the total extraction processes. Conversely, high total-recoverable to total ratios suggest that a larger fraction of the metal is held on exchanger sites or within poorly crystalline to amorphous compounds and thus can be removed more readily by weaker extraction procedures. Therefore, in region C, most of the manganese and zinc are held within the mineral matrices, whereas in region F, where higher amounts of organic carbon are available to adsorb the manganese or zinc, more of these metals may be found sorbed as organic chelates.

Relations Among Leachate

The ASTM, EP-TOX, and TCLP methods simulate leaching processes in soils under extreme conditions. Even though most metal concentrations in the leachates of soil samples from this study were below laboratory minimum reporting levels for all three methods, barium, and less commonly aluminum, iron, mercury, and zinc, were detected, and concentrations of these metals in the leachate were always a factor of 100 or more less than corresponding total or total-recoverable concentrations.

Spearman ranked correlation coefficients were calculated for barium, aluminum, iron, mercury, and zinc concentrations determined by the total or total-recoverable methods and by the ASTM, EP-TOX, and TCLP methods from 12 or fewer samples (results not shown). The only significant correlation at a 95 percent confidence level was for aluminum determined by the total-recoverable and TCLP methods. Therefore, for those metals tested, the readily soluble metals concentrations in these soils were apparently not dependent upon metals concentrations in the soil matrices.

Spearman ranked correlation coefficients were also calculated for barium, aluminum, iron, mercury, and zinc concentrations determined by the ASTM, EP-TOX, and TCLP methods, and particle size and organic carbon, from 12 or fewer samples (results not shown). The concentrations of most metals in the leachate did not significantly correlate with particle size or organic carbon either. Only concentrations of barium in the EP-TOX leachate significantly correlated with the amount of fine particles in the soil, and only concentrations of aluminum in the ASTM leachate significantly correlated with the amount of

organic carbon in the soil at a 95 percent confidence level. Therefore, for those metals tested, concentrations in the leachates are apparently not only independent of the concentrations of metals in the soil matrices, but also appear to be independent of the exchange capacity of the soils because the exchange capacity usually depends in part on the amount of organic material and fine particles in the soil.

Relations Between Metal Concentrations and Other Chemical and Physical Soil Characteristics

To gain further insight into factors that may affect the distribution of metals in the soils, Spearman ranked correlation coefficients between total or total-recoverable metals concentrations and between organic carbon concentrations or size fractions of soil particles were computed, and those pairs for which there is a 95 percent confidence that a correlation exists are identified (table 12).

Concentrations of most transition metals (specifically cobalt, copper, mercury, manganese, nickel, and zinc) determined by the total method correlate with organic carbon concentrations in the soil. Concentrations of other metals determined by the total method, such as aluminum, gallium, and phosphorus, likewise correlate with the content of organic carbon. Bohn and others (1985, p. 37) state, "Soil organic matter strongly adsorbs Cu^{2+} , Zn^{2+} , Fe (II and III), and other transition metal ions, probably as chelates." Therefore, it is likely that most metals listed in table 12 that demonstrate positive correlations with organic carbon are bound in part by organic chelates.

Trace metals may be adsorbed to exchanger sites on clays more preferentially than other cations (Kabata-Pendias and Pendias, 1984). Therefore metals concentrations will typically increase as the amount of material in the fine (silt and clay) fraction of the soil sample increases. In this study, total metals concentrations were determined only in the fine fraction; therefore, this concept could not be tested.

Unlike metals concentrations determined by the total method, those determined by the total-recoverable method for this study do not correlate with either organic carbon content or the fraction of fines in a sample (results not shown). Although organic carbon concentrations were only determined for fine fractions of soil, these results are surprising. They suggest that the metals concentrations

Table 12.--Correlation coefficients between concentrations of selected metals determined by the total method and organic carbon concentration and amount of silt and clay in soils in Washington

[Underlined values demonstrate a significant correlation at a 95 percent confidence level]

Metal	Spearman ranked correlation coefficients, in percent	
	Organic carbon	Silt and clay
Al	32	<u>-47</u>
As	-6	<u>-37</u>
Ba	<u>-36</u>	<u>41</u>
Co	31	<u>-41</u>
Cr	24	<u>-41</u>
Cu	<u>44</u>	<u>-33</u>
Fe	28	<u>-54</u>
Ga	<u>40</u>	<u>-51</u>
Hg	<u>40</u>	<u>-77</u>
K	<u>-42</u>	<u>38</u>
Mn	<u>41</u>	<u>-37</u>
Ni	28	<u>-41</u>
P	<u>55</u>	-22
Sc	28	<u>-53</u>
Sr	-20	<u>36</u>
Ti	20	<u>-47</u>
V	25	<u>-49</u>
Zn	<u>45</u>	<u>-70</u>

determined by the total-recoverable method are not simply dependent upon exchangeable metals concentrations, but also depend on the partial digestion of the various mineral phases present in the soils. Therefore, total-recoverable metals concentrations will vary between samples collected from soils that developed in different parent materials and in turn will depend on more subtle differences among different parent materials than metals concentrations determined by the total method.

SUMMARY AND CONCLUSIONS

The objective of this study was to obtain data on the magnitude and variability of background concentrations of metals in soils in selected regions throughout the State of

Washington and then to determine whether differences exist within or among selected regions. The State was initially divided into 24 regions, each with relatively uniform soils. Five samples were collected from 5 sites in each of 12 of the regions (for a total of 60 samples). A sample collected from a site consisted of a composite of five samples collected within an area of 1 acre. Samples were primarily taken from the B horizon at depths of 20 to 38 inches. The soil samples were then analyzed to determine metal concentrations as well as other chemical and physical properties.

Concentrations of various metals in the soil samples were determined by 5 different methods, a total (36 samples), a total-recoverable (60 samples), and 3 leaching methods (12 samples). In each method, a liquid was extracted from soil samples and was analyzed by atomic absorption or inductively-coupled plasma spectrometry to determine concentrations of metals. The differences among the methods were primarily in the extraction procedures and solvents used and secondly in the size of the particles analyzed; differences in the methods for determining metals concentrations in the extracts are not expected to affect the results greatly. The total method, which uses strong acids that digest nearly all the solid material, was used to determine 43 different metals in 3 samples from each region. The total-recoverable method, which consists of a partial extraction of the solid material by a mixture of strong acids, was used to determine concentrations of 16 different metals for all samples. One sample from each region was also analyzed by three methods, ASTM (American Society for Testing and Materials, method D3987-85), EP-TOX (method 1310; U.S. Environmental Protection Agency, 1986), and TCLP (method 1311; U.S. Environmental Protection Agency, 1990a, b), which simulated leaching conditions in soils. These methods were used to determine concentrations of 17 different metals. U.S. Environmental Protection Agency's inorganic priority pollutants are of primary interest and, as a result, were among the metals analyzed by every laboratory method.

Concentrations of metals determined by the total method are consistently greater and display less variability than values determined by the four other methods. Concentrations of mercury and nickel determined by the total method and of nickel, chromium, and copper determined by the total-recoverable method have the greatest variability statewide. Concentrations of zinc, lead, and arsenic determined by the total and total-recoverable methods vary the least. Particle-size distribution, carbon content, and soil-solution pH are also highly variable. For example, soils in regions O and P in the south-central and

southeastern parts of the State contain large amounts of silt and clay-size particles, whereas samples collected in region C on the west coast are primarily sand. Samples collected west of the Cascade Range also commonly contain greater amounts of organic carbon and are more acidic than samples collected in eastern Washington.

Most metals concentrations determined by either the total or total-recoverable method were sampled from populations that are either log-normally distributed or more nearly log-normally than normally distributed. Exceptions were concentrations of barium, gallium, potassium, and strontium determined by the total method, and concentrations of beryllium, manganese, and lead determined by the total-recoverable method that were sampled from populations that are normally distributed.

Results of the Kruskal-Wallis test show that, with the exceptions of copper and manganese concentrations determined by the total method, metals concentrations determined by either the total or the total-recoverable methods were significantly different among the different regions. However, this does not imply that the population means of all metals tested for each region are unique, nor does this statistical method indicate where differences of metals concentrations among the 12 regions are located.

The Fisher's Least Significant Difference test, used to distinguish differences among the 12 population means for each metal, showed that metals concentrations determined by the total method between many regions were not statistically distinct. Yet significant differences, such as those between region A and regions J and U, for which 4 of 11 metals tested were not statistically similar, do exist. Concentrations of metals determined by the total-recoverable method were not as similar among different regions as total metals concentrations. However, strong similarities exist between concentrations of total-recoverable metals in regions A and F and among concentrations of metals in regions O, P, and R. Furthermore, cluster analysis suggests that regions A, F, and part of D could be combined into two distinct groups, which would form an inner and outer ring of regions encircling Puget Sound. Cluster analysis also showed that regions O, P, and R could be combined to create two distinct regions in south-central and southeastern Washington. Based on this information and the results of the Kruskal-Wallis and Fisher's Least Significant Difference tests, further investigation could be conducted to provide more definitive relations between regions A and F and among regions O, P, and R.

Total and total-recoverable concentrations of seven metals (aluminum, arsenic, copper, chromium, iron, mercury, and nickel) were significantly correlated at a 95 percent confidence level. For these metals, Spearman ranked correlation coefficients ranged from 51 to 70 percent, and Pearson correlation coefficients ranged from 41 to 98 percent. Therefore, the bioavailability of these metals depended on the total concentrations in the fine-sized fractions of the soil. However, the form in which beryllium, manganese, lead, and zinc were held within the soil apparently varied too greatly to reach the same conclusion for these metals.

Concentrations of six metals determined by the total method correlated positively with organic carbon concentrations in the soil; a comparison between total metals concentrations and the amount of fines could not be determined. Total-recoverable metal concentrations did not correlate with either organic carbon content or amount of fines, which suggests that total-recoverable concentrations depend strongly upon the degree of partial digestion of various mineral phases. Therefore, total-recoverable metals concentrations reflect more subtle differences among different parent materials than total metals concentrations do.

Although the concentrations of most metals determined by the ASTM, EP-TOX, and TCLP methods were below laboratory minimum reporting levels, concentrations of barium, and less commonly aluminum, iron, mercury, and zinc, were detected in the leachate. These concentrations were always a factor of 100 or more less than concentrations determined by the total or total-recoverable methods. Readily soluble metals concentrations in the soils were apparently not dependent upon metals concentrations in the soils matrices or on the amount of organic material and fine particles in the soil. However, the analytical precision of these methods is poor, and the concentrations did not correlate well with concentrations determined by the total or total-recoverable method or with the amount of fines or organic carbon in the soil. As a result, estimations of baseline concentrations of metals determined by the ASTM, EP-TOX, and TCLP methods for this study are much less accurate than estimations of baseline concentrations of metals determined by the total and total-recoverable methods.

Finally, this study provides a good foundation from which future studies may develop. Benefits of regionalized studies, as well as benefits from the implementation of additional analytical tools, more complete inferences may be made from the various mechanisms driving the chemistry in the soils.

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APPENDIX A.--DATA TABLES

Table A1.--Concentrations of metals in soils in Washington determined by the total method

[Concentrations are in milligrams per kilogram (except values for Al, Ca, Fe, K, Mg, Na, P, and Ti, which are given in percent); <, less than; (dup), duplicate of preceding sample]

Sample number (fig. 2)	Ag	Al	As	Au	Ba	Be	Bi	Ca	Cd	Ce	Co
A2	<2	10.0	6.4	<8	330	<1	<10	0.4	<2	20	8
A3	<2	9.0	3.8	<8	340	1	<10	1.6	<2	65	48
A5	<2	7.5	7.6	<8	540	1	<10	.7	<2	54	14
A6(dup)	<2	8.9	11.	<8	530	1	<10	.6	<2	62	13
C1	<2	6.7	9.1	<8	360	1	<10	2.3	<2	49	35
C3	<2	8.1	13.	<8	510	1	<10	2.8	<2	63	28
C4	<2	8.0	20.	<8	480	2	<10	3.3	<2	81	33
D1	<2	8.3	3.9	<8	580	1	<10	1.5	<2	70	17
D4	<2	9.3	8.2	<8	700	1	<10	1.6	<2	52	19
D5	<2	10.0	13.	<8	670	1	<10	.8	<2	64	21
F1	<2	11.0	5.4	<8	570	2	<10	1.8	<2	67	19
F2	<2	8.2	4.9	<8	330	1	<10	1.1	<2	42	12
F6(dup)	<2	8.1	4.7	<8	330	1	<10	1.1	<2	41	12
F5	<2	7.0	6.	<8	300	<1	<10	1.8	<2	26	47
G1	<2	10.0	5.5	<8	670	2	<10	1.0	<2	65	27
G4	<2	9.2	8.5	<8	590	1	<10	.9	6	59	24
G5	<2	7.7	6.5	<8	690	2	<10	.8	<2	73	16
J2	<2	7.1	1.5	<8	750	1	<10	1.8	<2	50	8
J3	<2	7.8	5.3	<8	920	2	<10	2.0	<2	100	16
J5	<4	7.3	2.2	<20	870	<2	<20	2.0	<4	69	10
L1	<2	9.9	.8	<8	550	2	<10	2.3	<2	40	26
L2	<2	9.2	13.	<8	630	2	<10	1.7	<2	52	18
L4	<2	8.8	5.	<8	710	2	<10	2.0	5	57	14
L6(dup)	<2	8.7	5.3	<8	690	2	<10	2.0	<2	55	14
M1	<2	8.3	1.9	<8	520	1	<10	2.7	<2	41	23
M2	<2	8.3	2.4	<8	470	1	<10	2.1	<2	40	26
M4	<2	7.9	2.1	<8	510	1	<10	2.6	<2	45	18
O2	<2	7.0	7.2	<8	660	2	<10	5.5	<2	82	16
O3	<2	7.7	5.1	<8	610	2	<10	3.7	<2	57	16
O4	<2	7.5	6.6	<8	650	2	<10	3.9	<2	72	23
P2	<2	7.0	4.8	<8	650	2	<10	1.9	<2	71	15
P3	<2	7.5	3.9	<8	670	2	<10	1.7	<2	64	14
P6(dup)	<2	7.5	3.9	<8	670	2	<10	1.7	<2	65	14
P4	<2	7.3	10.	<8	700	2	<10	1.7	<2	49	10
P5	<2	7.0	2.1	<8	680	1	<10	1.7	<2	52	10

Table A1.--Concentrations of metals in soils in Washington determined by the total method--Continued

Sample number	Ag	Al	As	Au	Ba	Be	Bi	Ca	Cd	Ce	Co
R1	<2	6.9	8.1	<8	710	2	<10	3.0	<2	93	41
R3	<2	7.2	3.4	<8	660	2	<10	1.9	<2	72	12
R4	<2	6.8	5.5	<8	580	1	<10	3.7	<2	110	22
U1	<2	7.9	16.	<8	670	2	<10	1.3	<2	64	13
U2	<2	8.3	6.6	<8	650	2	<10	1.3	<2	69	12
U5	<2	7.5	7.1	<8	780	2	<10	1.5	<2	84	11
RS1	<2	7.7	4.3	<8	480	<1	<10	1.8	<2	40	13
RS(dup)	<2	7.8	4.3	<8	490	<1	<10	1.8	<2	40	13

Sample number	Cr	Cu	Eu	Fe	Ga	Hg	Ho	K	La	Li	Mg	Mn
A2	100	29	<2	5.2	23	0.16	<4	0.9	28	40	0.7	410
A3	170	120	2	8.8	23	.22	<4	.6	27	25	2.0	1,500
A5	83	28	<2	4.1	18	.20	<4	1.1	28	31	.6	680
A6(dup)	79	32	<2	5.2	21	.14	<4	1.0	28	34	.7	650
C1	160	42	<2	6.1	16	5.9	<4	1.1	24	43	2.3	1,300
C3	120	23	<2	5.9	20	6.	<4	1.4	33	37	1.6	820
C4	150	27	2	6.9	23	.20	<4	1.0	42	25	1.6	800
D1	140	13	<2	3.4	21	.06	<4	1.0	40	36	.9	550
D4	130	28	<2	3.9	23	.10	<4	1.7	29	36	1.4	580
D5	340	68	<2	6.0	23	.38	<4	1.4	28	62	2.0	690
F1	99	53	<2	5.2	28	.26	<4	1.1	27	52	1.2	740
F2	50	30	<2	3.0	18	.08	<4	.5	20	20	.6	1,400
F6(dup)	51	31	<2	3.0	18	.10	<4	.5	20	19	.6	1,400
F5	540	29	<2	4.9	12	.06	<4	.6	15	29	3.5	750
G1	81	39	2	8.8	27	.06	<4	.9	35	24	.9	1,100
G4	59	49	<2	5.8	21	.08	<4	1.2	29	25	.8	970
G5	64	27	<2	5.4	20	.06	<4	1.7	39	24	.8	620
J2	42	30	<2	2.5	17	.06	<4	1.8	30	27	.6	630
J3	84	31	<2	4.1	20	.04	<4	2.2	60	31	1.1	780
J5	49	30	<4	2.5	10	.04	<4	1.8	41	24	.6	670
L1	260	53	<2	5.4	26	.04	<4	1.8	26	89	2.1	910
L2	96	33	<2	4.1	24	.04	<4	2.3	31	49	1.2	720
L4	78	28	<2	4.1	21	.04	<4	1.8	35	38	1.1	670
L6(dup)	67	30	<2	4.1	21	.06	<4	1.7	33	39	1.1	680

Table A1.--Concentrations of metals in soils in Washington determined by the total method--Continued

Sample number (fig. 2)	Cr	Cu	Eu	Fe	Ga	Hg	Ho	K	La	Li	Mg	Mn
M1	61	28	<2	7.7	21	0.08	<4	1.1	26	27	1.1	750
M2	120	44	<2	7.4	21	.08	<4	1.0	26	30	1.2	1,000
M4	57	28	<2	4.6	19	.06	<4	1.2	28	22	1.0	790
O2	77	27	<2	3.8	17	.04	<4	1.7	47	33	1.5	640
O3	68	30	<2	4.3	19	.06	<4	1.6	35	31	1.2	600
O4	61	29	<2	5.7	20	.06	<4	1.6	40	29	1.6	860
P2	53	28	<2	4.0	17	.04	<4	1.7	40	26	.8	690
P3	56	27	<2	4.0	18	.04	<4	1.6	36	28	.8	670
P6(dup)	54	25	<2	4.0	18	.04	<4	1.7	39	27	.8	670
P4	28	22	<2	2.8	18	.04	<4	1.6	27	27	.6	560
P5	34	23	<2	2.8	16	.04	<4	1.7	29	26	.7	550
R1	55	85	<2	9.3	20	.68	<4	1.6	44	26	2.0	1,600
R3	42	26	<2	3.8	16	.04	<4	1.7	42	27	1.0	550
R4	68	24	<2	6.0	18	.04	<4	1.4	61	22	1.6	940
U1	56	26	<2	4.6	20	.10	<4	2.2	39	36	1.0	560
U2	50	37	<2	3.8	19	.08	<4	1.8	40	49	1.5	640
U5	69	24	<2	3.3	17	.04	<4	2.3	50	35	1.0	540
RS1	120	21	<2	3.2	16	.12	<4	.9	19	17	.8	560
RS2	110	19	<2	3.2	16	.12	<4	.9	19	17	.8	570

Sample number (fig. 2)	Mo	Na	Nb	Nd	Ni	P	Pb	Sb	Se	Sc	Sn
A2	2	6.2	10	23	33	0.04	13	1.3	1.2	18	<5
A3	2	1.0	13	33	76	.17	4	1.0	1.2	34	<5
A5	<2	1.0	13	22	24	.08	10	1.4	.2	14	<5
A6(dup)	<2	.8	16	21	24	.08	11	1.2	.3	17	<5
C1	<2	2.0	10	28	62	.10	12	1.3	.3	23	<5
C3	<2	2.2	12	37	55	.12	15	1.4	.4	21	<5
C4	2	2.0	10	48	34	.17	15	1.9	.3	34	<5
D1	<2	2.3	7	34	66	.06	11	1.3	.2	11	<5
D4	<2	1.8	7	25	73	.09	9	1.7	.1	15	<5
D5	<2	1.2	5	28	120	.17	7	3.8	.7	24	<5
F1	<3	2.2	10	24	49	.13	14	1.4	.4	18	<5
F2	<2	.9	6	19	23	.47	8	1.2	.5	11	<5
F6(dup)	<2	.9	5	19	21	.47	8	1.0	.4	11	<5
F5	<2	2.2	<4	16	470	.02	5	1.1	.1	18	<5

Table A1.--Concentrations of metals in soils in Washington determined by the total method--Continued

Sample number (fig. 2)	Mo	Na	Nb	Nd	Ni	P	Pb	Sb	Se	Sc	Sn
G1	2	0.9	13	42	27	0.18	12	1.3	0.3	34	<5
G4	2	1.1	10	25	22	.19	14	1.5	.2	18	<5
G5	<2	1.2	12	35	23	.11	15	1.6	.3	18	<5
J2	<2	2.3	7	25	12	.10	12	.7	1.0	10	<5
J3	<2	2.1	14	47	30	.14	17	1.7	.1	14	<5
J5	<4	2.3	10	35	20	.10	10	1.2	<.1	9	<10
L1	<2	1.7	4	27	70	.11	13	.6	.1	24	<5
L2	<2	1.6	9	29	36	.13	16	1.6	.2	15	<5
L4	<2	2.0	7	30	30	.10	12	1.0	.1	16	<5
L6(dup)	<2	1.9	8	32	32	.10	11	1.1	.1	16	<5
M1	<2	1.5	8	27	15	.14	10	.8	.1	38	<5
M2	<2	1.2	8	28	48	.14	7	.8	.2	34	<5
M4	<2	2.0	7	29	20	.11	12	.8	<.1	17	<5
O2	<2	1.6	9	41	28	.10	15	1.6	<.1	13	<5
O3	<2	1.6	7	33	28	.09	11	1.2	.1	16	<5
O4	<2	1.6	10	39	27	.13	14	1.7	.1	20	<5
P2	<2	1.8	6	36	18	.14	11	1.2	.1	14	<5
P3	2	1.7	8	33	16	.12	10	1.1	.1	14	<5
P6(dup)	<2	1.7	9	36	16	.13	11	1.2	.1	14	<5
P4	<2	2.2	7	26	11	.12	11	.7	<.1	11	<5
P5	2	2.2	6	27	11	.10	10	1.0	<.1	10	<5
R1	<2	1.3	14	42	32	.21	36	3.8	<.1	27	<5
R3	<2	2.0	8	37	18	.08	10	.8	<.1	13	<5
R4	<2	1.8	11	55	24	.13	12	1.5	.1	20	<5
U1	<2	1.3	10	36	20	.08	20	1.9	.1	16	<5
U2	<2	1.3	8	36	24	.05	21	1.3	.1	14	<5
U5	<2	1.7	12	38	21	.08	16	1.2	<.1	12	<5
RS1	<2	2.0	4	18	45	.11	8	1.2	.3	13	<5
RS(dup)	<2	2.1	5	20	44	.11	7	1.3	.3	13	<5

Sample number (fig. 2)	Sr	Ta	Th	Ti	U	V	Y	Yb	Zn
A2	92	<40	11	0.68	<100	150	12	1	80
A3	180	<40	5	1.20	<100	270	35	3	100
A5	150	<40	9	.77	<100	130	10	1	95
A6(dup)	130	<40	9	.84	<100	160	10	1	96

Table A1.--Concentrations of metals in soils in Washington determined by the total method--Continued

Sample number (fig. 2)	Sr	Ta	Th	Ti	U	V	Y	Yb	Zn
C1	230	<40	6	0.68	<100	170	23	2	280
C3	320	<40	7	.72	<100	160	27	3	140
C4	300	<40	8	1.20	<100	370	44	4	130
D1	310	<40	10	.51	<100	99	14	1	110
D4	350	<40	9	.43	<100	120	14	1	89
D5	120	<40	10	.67	<100	210	27	3	130
F1	280	<40	7	.72	<100	140	19	2	120
F2	170	<40	6	.34	<100	71	16	2	76
F6(dup)	170	<40	6	.35	<100	73	16	2	77
F5	150	<40	5	.46	<100	130	13	1	69
G1	170	<40	11	1.30	<100	270	36	4	130
G4	180	<40	8	.90	<100	180	17	2	120
G5	190	<40	12	.87	<100	170	18	2	94
J2	350	<40	8	.33	<100	57	22	2	67
J3	450	<40	16	.49	<100	110	24	3	93
J5	460	<80	8	.34	<200	60	21	2	65
L1	320	<40	7	.53	<100	170	22	2	160
L2	360	<40	9	.48	<100	100	21	2	110
L4	390	<40	10	.51	<100	110	22	2	82
L6(dup)	380	<40	10	.50	<100	110	22	2	82
M1	270	<40	5	.92	<100	210	30	3	97
M2	200	<40	7	.78	<100	210	36	4	110
M4	330	<40	6	.66	<100	130	21	2	81
O2	330	<40	13	.48	<100	110	21	2	70
O3	300	<40	9	.53	<100	110	22	2	76
O4	300	<40	10	.86	<100	190	25	3	88
P2	270	<40	10	.57	<100	100	23	2	73
P3	280	<40	10	.57	<100	100	23	2	72
P6(dup)	280	<40	10	.59	<100	100	23	2	69
P4	290	<40	7	.42	<100	66	23	3	63
P5	290	<40	7	.42	<100	69	20	2	61
R1	240	<40	12	1.20	<100	250	38	4	180
R3	300	<40	10	.53	<100	98	23	2	66
R4	330	<40	17	.89	<100	190	25	3	84

Table A1.--Concentrations of metals in soils in Washington determined by the total method--Continued

Sample number (fig. 2)	Sr	Ta	Th	Ti	U	V	Y	Yb	Zn
U1	230	<40	14	0.60	<100	110	23	2	96
U2	220	<40	11	.49	<100	81	26	3	86
U5	350	<40	14	.39	<100	77	23	2	70
RS1	270	<40	5	.45	<100	98	15	2	53
RS(dup)	270	<40	5	.45	<100	99	16	2	54

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods

[Concentrations are in milligrams per kilogram of dry soil, except total and total- recoverable values for iron and aluminum, which are given in percent, and values in parentheses, which are given in milligrams per liter of leachate; <, less than; >, greater than; --, no data; *, estimated value; +, detected in blank; (dup), duplicate of preceding sample; ASTM, American Society for Testing Materials method D3987-85; EP-TOX, Extraction Procedure-Toxicity test; TCLP, Toxicity Characteristic Leaching Procedure]

Sample number	Silver							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	<0.2	--	--	--	--	--	--
A2	<2	<2	<0.04	(<.002)	<0.04	(<.002)	<0.04	(<.002)
A3	<2	<2	--	--	--	--	--	--
A4	--	<2	--	--	--	--	--	--
A5	<2	<2	--	--	--	--	--	--
A6(dup)	<2	<2	--	--	--	--	--	--
C1	<2	<2	--	--	--	--	--	--
C2	--	<2	--	--	--	--	--	--
C3	<2	<2	--	--	--	--	--	--
C4	<2	<2	--	--	--	--	--	--
C5	--	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
D1	<2	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
D2	--	<2	--	--	--	--	--	--
D3	--	<2	--	--	--	--	--	--
D4	<2	<2	--	--	--	--	--	--
D5	<2	.34*	--	--	--	--	--	--
F1	<2	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
F2	<2	<2	--	--	--	--	--	--
F6(dup)	<2	<2	--	--	--	--	--	--
F3	--	<2	--	--	--	--	--	--
F4	--	<2	--	--	--	--	--	--
F5	<2	<2	--	--	--	--	--	--
G1	<2	<2	--	--	--	--	--	--
G2	--	<2	--	--	--	--	--	--
G3	--	<2	--	--	--	--	--	--
G4	<2	<2	--	--	--	--	--	--
G5	<2	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
J1	--	.31*	--	--	--	--	--	--
J2	<2	<2	--	--	--	--	--	--
J3	<2	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
J4	--	<2	--	--	--	--	--	--
J5	<4	<2	--	--	--	--	--	--
L1	<2	0.29*	--	--	--	--	--	--
L2	<2	<2	--	--	--	--	--	--
L3	--	<2	--	--	--	--	--	--
L4	<2	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
L6(dup)	<2	<2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
L5	--	<2	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Silver							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
M1	<2	0.58*	--	--	--	--	--	--
M2	<2	.58*	--	--	--	--	--	--
M3	--	.24*	--	--	--	--	--	--
M4	<2	.35*	<0.04	(<0.002)	<0.04	(<0.002)	<0.04	(<0.002)
M5	--	.39*	--	--	--	--	--	--
O1	--	<.2	--	--	--	--	--	--
O2	<2	<.2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
O3	<2	<.2	--	--	--	--	--	--
O4	<2	.25*	--	--	--	--	--	--
O5	--	<.2	--	--	--	--	--	--
P1	--	.41*	--	--	--	--	--	--
P2	<2	<.2	--	--	--	--	--	--
P3	<2	.32*	--	--	--	--	--	--
P6(dup)	<2	<.2	--	--	--	--	--	--
P4	<2	<.2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
P5	<2	<.2	--	--	--	--	--	--
R1	<2	<.2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
R2	--	.25*	--	--	--	--	--	--
R3	<2	<.2	--	--	--	--	--	--
R4	<2	<.2	--	--	--	--	--	--
R6(dup)	--	<.2	--	--	--	--	--	--
R5	--	<.2	--	--	--	--	--	--
U1	<2	<.2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
U2	<2	<.2	--	--	--	--	--	--
U3	--	<.2	--	--	--	--	--	--
U6(dup)	--	<.2	--	--	--	--	--	--
U4	--	<.2	--	--	--	--	--	--
U5	<2	<.2	--	--	--	--	--	--
RS1	<2	<.2	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
RS(dup)	<2	<.2	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Aluminum							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	5.4	--	--	--	--	--	--
A2	10.0	5.1	2.2	(.11)	<1.0	(<.05)	47.0	(2.35)
A3	9.0	5.2	--	--	--	--	--	--
A4	--	2.9	--	--	--	--	--	--
A5	7.5	3.8	--	--	--	--	--	--
A6(dup)	8.9	4.3	--	--	--	--	--	--
C1	6.7	.7	--	--	--	--	--	--
C2	--	.7	--	--	--	--	--	--
C3	8.1	.6	--	--	--	--	--	--
C4	8.0	.6	--	--	--	--	--	--
C5	--	.7	1.8	(.09)	<1.0	(<.05)	20.6	(1.03)
D1	8.3	2.2	2.4	(.12)	1.5	(.08)	14.3	(.72)
D2	--	1.7	--	--	--	--	--	--
D3	--	1.6	--	--	--	--	--	--
D4	9.3	2.5	--	--	--	--	--	--
D5	10.0	4.6	--	--	--	--	--	--
F1	11.0	3.8	3.6	(.18)	<1.0	(<.05)	23.2	(1.16)
F2	8.2	4.0	--	--	--	--	--	--
F6(dup)	8.1	3.7	--	--	--	--	--	--
F3	--	2.9	--	--	--	--	--	--
F4	--	3.0	--	--	--	--	--	--
F5	7.0	2.4	--	--	--	--	--	--
G1	10.0	4.7	--	--	--	--	--	--
G2	--	1.8	--	--	--	--	--	--
G3	--	1.9	--	--	--	--	--	--
G4	9.2	4.0	--	--	--	--	--	--
G5	7.7	3.4	<1.0	(<.05)	<1.0	(<.05)	6.4	(.32)
J1	--	2.0	--	--	--	--	--	--
J2	7.1	1.3	--	--	--	--	--	--
J3	7.8	.9	1.5	(.08)	<1.0	(<.05)	1.4	(.07)
J4	--	.8	--	--	--	--	--	--
J5	7.3	1.0	--	--	--	--	--	--
L1	9.9	2.6	--	--	--	--	--	--
L2	9.2	2.6	--	--	--	--	--	--
L3	--	2.9	--	--	--	--	--	--
L4	8.8	1.7	1.9	(.10)	<1.0	(<.05)	<1.0	(<.05)
L6(dup)	8.7	1.7	1.2	(.06)	<1.0	(<.05)	1.1	(.06)
L5	--	2.1	--	--	--	--	--	--
M1	8.3	2.8	--	--	--	--	--	--
M2	8.3	2.6	--	--	--	--	--	--
M3	--	1.6	--	--	--	--	--	--
M4	7.9	2.0	<1.0	(<.05)	<1.0	(<.05)	3.0	(.15)
M5	--	2.6	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Aluminum							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	1.1	--	--	--	--	--	--
O2	7.0	1.4	<1.0	(<0.05)	23.8	(0.119)	16.4	(0.82)
O3	7.7	1.5	--	--	--	--	--	--
O4	7.5	1.2	--	--	--	--	--	--
O5	--	1.2	--	--	--	--	--	--
P1	--	1.9	--	--	--	--	--	--
P2	7.0	1.5	--	--	--	--	--	--
P3	7.5	2.3	--	--	--	--	--	--
P6(dup)	7.5	2.0	--	--	--	--	--	--
P4	7.3	1.5	3.1	(.15)	<1.0	(<.05)	2.1	(.11)
P5	7.0	1.5	--	--	--	--	--	--
R1	6.9	.6	3.3	(.17)	<1.0	(<.05)	11.5	(.58)
R2	--	.7	--	--	--	--	--	--
R3	7.2	1.0	--	--	--	--	--	--
R4	6.8	.9	--	--	--	--	--	--
R6(dup)	--	.9	--	--	--	--	--	--
R5	--	.8	--	--	--	--	--	--
U1	7.9	1.3	1.1	(.05)	<1.0	(<.05)	5.3	(.27)
U2	8.3	2.1	--	--	--	--	--	--
U3	--	1.6	--	--	--	--	--	--
U6(dup)	--	1.7	--	--	--	--	--	--
U4	--	1.3	--	--	--	--	--	--
U5	7.5	1.4	--	--	--	--	--	--
RS1	7.7	1.6	<1.0	(<.05)	1.2	(.06)	11.4	(.52)
RS(dup)	7.8	1.6	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Arsenic							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	4.6	--	--	--	--	--	--
A2	6.4	3.5	<0.6	(<.03)	<0.6	(<.03)	<0.6	(<.03)
A3	3.8	1.9	--	--	--	--	--	--
A4	--	1.8	--	--	--	--	--	--
A5	7.6	8.1	--	--	--	--	--	--
A6(dup)	11	8.4	--	--	--	--	--	--
C1	9.1	2.9	--	--	--	--	--	--
C2	--	2.8	--	--	--	--	--	--
C3	13	1.8	--	--	--	--	--	--
C4	20	1.7	--	--	--	--	--	--
C5	--	2.3	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
D1	3.9	2.8	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
D2	--	1.9	--	--	--	--	--	--
D3	--	2.6	--	--	--	--	--	--
D4	8.2	4.7	--	--	--	--	--	--
D5	13	9	--	--	--	--	--	--
F1	5.4	1.2	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
F2	4.9	2	--	--	--	--	--	--
F6(dup)	4.7	3.3	--	--	--	--	--	--
F3	--	2	--	--	--	--	--	--
F4	--	4.9	--	--	--	--	--	--
F5	6	4.2	--	--	--	--	--	--
G1	5.5	2.9	--	--	--	--	--	--
G2	--	1.5	--	--	--	--	--	--
G3	--	2.8	--	--	--	--	--	--
G4	8.5	5.5	--	--	--	--	--	--
G5	6.5	6.9	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
J1	--	5.3	--	--	--	--	--	--
J2	1.5	1.1	--	--	--	--	--	--
J3	5.3	2.9	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
J4	--	1.1	--	--	--	--	--	--
J5	2.2	1.4	--	--	--	--	--	--
L1	.8	<.5	--	--	--	--	--	--
L2	13	7.2	--	--	--	--	--	--
L3	--	1.4	--	--	--	--	--	--
L4	5	2.3	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
L6(dup)	5.3	2.1	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
L5	--	>.5	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Arsenic							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
M1	1.9	1	--	--	--	--	--	--
M2	2.4	1.1	--	--	--	--	--	--
M3	--	3	--	--	--	--	--	--
M4	2.1	2.1	<0.6	(<0.03)	<0.6	(<0.03)	<0.6	(<0.03)
M5	--	1.8	--	--	--	--	--	--
O1	--	3.8	--	--	--	--	--	--
O2	7.2	5.5	1.6	(.08)	1.6	(.08)	2.3	(.12)
O3	5.1	3.6	--	--	--	--	--	--
O4	6.6	5	--	--	--	--	--	--
O5	--	3.2	--	--	--	--	--	--
P1	--	4.1	--	--	--	--	--	--
P2	4.8	3.7	--	--	--	--	--	--
P3	3.9	2.6	--	--	--	--	--	--
P6(dup)	3.9	2.3	--	--	--	--	--	--
P4	10	1.2	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
P5	2.1	1.5	--	--	--	--	--	--
R1	8.1	1.4	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
R2	--	3.7	--	--	--	--	--	--
R3	3.4	2.6	--	--	--	--	--	--
R4	5.5	2.5	--	--	--	--	--	--
R6(dup)	--	2.5	--	--	--	--	--	--
R5	--	6.1	--	--	--	--	--	--
U1	16	9.4	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
U2	6.6	5.8	--	--	--	--	--	--
U3	--	5.7	--	--	--	--	--	--
U6(dup)	--	6.1	--	--	--	--	--	--
U4	--	8.8	--	--	--	--	--	--
U5	7.1	6.2	--	--	--	--	--	--
RS1	4.3	2.5	<.6	(<.03)	<.6	(<.03)	<.6	(<.03)
RS(dup)	4.3	2.7	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Barium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	--	--	--	--	--	--	--
A2	330	--	0.2	(0.01)	0.8	(0.04)	7.0	(0.35)
A3	340	--	--	--	--	--	--	--
A4	--	--	--	--	--	--	--	--
A5	540	--	--	--	--	--	--	--
A6(dup)	530	--	--	--	--	--	--	--
C1	360	--	--	--	--	--	--	--
C2	--	--	--	--	--	--	--	--
C3	510	--	--	--	--	--	--	--
C4	480	--	--	--	--	--	--	--
C5	--	--	.3	(.02)	.8	(.04)	3.0	(.15)
D1	580	--	.4	(.02)	1.8	(.09)	7.9	(.39)
D2	--	--	--	--	--	--	--	--
D3	--	--	--	--	--	--	--	--
D4	700	--	--	--	--	--	--	--
D5	670	--	--	--	--	--	--	--
F1	570	--	.2	(.01)	1.5	(.08)	12.3	(.62)
F2	330	--	--	--	--	--	--	--
F6(dup)	330	--	--	--	--	--	--	--
F3	--	--	--	--	--	--	--	--
F4	--	--	--	--	--	--	--	--
F5	300	--	--	--	--	--	--	--
G1	670	--	--	--	--	--	--	--
G2	--	--	--	--	--	--	--	--
G3	--	--	--	--	--	--	--	--
G4	590	--	--	--	--	--	--	--
G5	690	--	.7	(.03)	1.4	(.07)	19.1	(.96)
J1	--	--	--	--	--	--	--	--
J2	750	--	--	--	--	--	--	--
J3	920	--	1.2	(.06)	2.0	(.10)	8.3	(.41)
J4	--	--	--	--	--	--	--	--
J5	870	--	--	--	--	--	--	--
L1	550	--	--	--	--	--	--	--
L2	630	--	--	--	--	--	--	--
L3	--	--	--	--	--	--	--	--
L4	710	--	.1	(.01)	.9	(.05)	10.1	(.51)
L6(dup)	690	--	1.8	(.09)	.6	(.03)	10.3	(.51)
L5	--	--	--	--	--	--	--	--
M2	470	--	--	--	--	--	--	--
M3	--	--	--	--	--	--	--	--
M4	510	--	.4	(.02)	2.6	(.13)	12.1	(.60)
M5	--	--	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Barium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	--	--	--	--	--	--	--
O2	660	--	0.8	(0.04)	18.1	(0.91)	18.3	(0.91)
O3	610	--	--	--	--	--	--	--
O4	650	--	--	--	--	--	--	--
O5	--	--	--	--	--	--	--	--
P1	--	--	--	--	--	--	--	--
P2	650	--	--	--	--	--	--	--
P3	670	--	--	--	--	--	--	--
P6(dup)	670	--	--	--	--	--	--	--
P4	700	--	2.4	(.12)	3.0	(.15)	14.6	(.73)
P5	680	--	--	--	--	--	--	--
R1	710	--	.3	(.02)	1.0	(.05)	5.9	(.29)
R2	--	--	--	--	--	--	--	--
R3	660	--	--	--	--	--	--	--
R4	580	--	--	--	--	--	--	--
R6(dup)	--	--	--	--	--	--	--	--
R5	--	--	--	--	--	--	--	--
U1	670	--	.7	(.04)	.8	(.04)	14.5	(.72)
U2	650	--	--	--	--	--	--	--
U3	--	--	--	--	--	--	--	--
U6(dup)	--	--	--	--	--	--	--	--
U4	--	--	--	--	--	--	--	--
U5	780	--	--	--	--	--	--	--
RS1	480	--	.6	(.03)	1.0	(.05)	15.6	(.78)
RS(dup)	490	--	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Beryllium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	0.5	--	--	--	--	--	--
A2	<1	.4	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
A3	1	.7	--	--	--	--	--	--
A4	--	.7	--	--	--	--	--	--
A5	1	.9	--	--	--	--	--	--
A6(dup)	1	.9	--	--	--	--	--	--
C1	1	.1	--	--	--	--	--	--
C2	--	.1	--	--	--	--	--	--
C3	1	.1	--	--	--	--	--	--
C4	2	.1	--	--	--	--	--	--
C5	--	.1	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D1	1	.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D2	--	.4	--	--	--	--	--	--
D3	--	.3	--	--	--	--	--	--
D4	1	.6	--	--	--	--	--	--
D5	1	.6	--	--	--	--	--	--
F1	2	.8	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
F2	1	.7	--	--	--	--	--	--
F6(dup)	1	.7	--	--	--	--	--	--
F3	--	.5	--	--	--	--	--	--
F4	--	.6	--	--	--	--	--	--
F5	<1	.2	--	--	--	--	--	--
G1	2	1	--	--	--	--	--	--
G2	--	.4	--	--	--	--	--	--
G3	--	.8	--	--	--	--	--	--
G4	1	.7	--	--	--	--	--	--
G5	2	.9	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J1	--	.7	--	--	--	--	--	--
J2	1	.3	--	--	--	--	--	--
J3	2	.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J4	--	.3	--	--	--	--	--	--
J5	<2	.2	--	--	--	--	--	--
L1	2	.8	--	--	--	--	--	--
L2	2	.8	--	--	--	--	--	--
L3	--	1.1	--	--	--	--	--	--
L4	2	.4	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L6(dup)	2	.5	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L5	--	.6	--	--	--	--	--	--
M1	1	1.4	--	--	--	--	--	--
M2	1	1.1	--	--	--	--	--	--
M3	--	.7	--	--	--	--	--	--
M4	1	.8	<0.4	(<.02)	<.4	(<.02)	<.4	(<.02)
M5	--	.8	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Beryllium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	0.5	--	--	--	--	--	--
O2	2	.6	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
O3	2	.6	--	--	--	--	--	--
O4	2	.7	--	--	--	--	--	--
O5	--	.4	--	--	--	--	--	--
P1	--	.8	--	--	--	--	--	--
P2	2	.5	--	--	--	--	--	--
P3	2	.8	--	--	--	--	--	--
P6(dup)	2	.7	--	--	--	--	--	--
P4	2	.6	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
P5	1	.5	--	--	--	--	--	--
R1	2	.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
R2	--	.4	--	--	--	--	--	--
R3	2	.5	--	--	--	--	--	--
R4	1	.3	--	--	--	--	--	--
R6(dup)	--	.2	--	--	--	--	--	--
R5	--	.3	--	--	--	--	--	--
U1	2	.5	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
U2	2	.6	--	--	--	--	--	--
U3	--	.5	--	--	--	--	--	--
U6(dup)	--	.6	--	--	--	--	--	--
U4	--	.5	--	--	--	--	--	--
U5	2	.5	--	--	--	--	--	--
RS1	<1	.1	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
RS(dup)	<1	.1	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Cadmium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	<0.2*	--	--	--	--	--	--
A2	<2	<.2*	0.05*	(0.003)	<0.04	(<0.002)	<0.04	(<0.002)
A3	<2	<.2*	--	--	--	--	--	--
A4	--	<.2*	--	--	--	--	--	--
A5	<2	<.2*	--	--	--	--	--	--
A6(dup)	<2	<.2*	--	--	--	--	--	--
C1	<2	<.2*	--	--	--	--	--	--
C2	--	<.2*	--	--	--	--	--	--
C3	<2	<.2*	--	--	--	--	--	--
C4	2	<.2*	--	--	--	--	--	--
C5	--	<.2*	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
D1	2	<.2*	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
D2	--	<.2*	--	--	--	--	--	--
D3	--	<.2*	--	--	--	--	--	--
D4	<2	<.2*	--	--	--	--	--	--
D5	<2	<.2*	--	--	--	--	--	--
F1	<2	<.2*	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
F2	<2	<.2*	--	--	--	--	--	--
F6(dup)	<2	<.2*	--	--	--	--	--	--
F3	--	<.2*	--	--	--	--	--	--
F4	--	<.2*	--	--	--	--	--	--
F5	<2	<.2*	--	--	--	--	--	--
G1	<2	<.2*	--	--	--	--	--	--
G2	--	<.2*	--	--	--	--	--	--
G3	--	<.2*	--	--	--	--	--	--
G4	6	<.2*	--	--	--	--	--	--
G5	<2	<.2*	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
J1	--	<.2*	--	--	--	--	--	--
J2	<2	<.2*	--	--	--	--	--	--
J3	<2	<.2*	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
J4	--	<.2*	--	--	--	--	--	--
J5	<4	<.2*	--	--	--	--	--	--
L1	<2	<.2*	--	--	--	--	--	--
L2	<2	<.2*	--	--	--	--	--	--
L3	--	<.2*	--	--	--	--	--	--
L4	5	<.2*	.04*	(.002)	<.04	(<.002)	<.04	(<.002)
L6(dup)	<2	<.2*	<.04	(<.002)	<.04	(<.002)	<.04	(<.002)
L5	--	<.2*	--	--	--	--	--	--
M1	<2	<.2*	--	--	--	--	--	--
M2	<2	<.2*	--	--	--	--	--	--
M3	--	<.2*	--	--	--	--	--	--
M4	<2	<.2*	.05*	(.003)	<.04	(<.002)	<.04	(<.002)
M5	--	<.2*	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Cadmium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	<0.2*	--	--	--	--	--	--
O2	<2	<2*	<0.04	(<0.002)	<0.04	(<0.002)	<0.04	(<0.002)
O3	<2	<2*	--	--	--	--	--	--
O4	<2	<2*	--	--	--	--	--	--
O5	--	<2*	--	--	--	--	--	--
P1	--	<2*	--	--	--	--	--	--
P2	<2	<2*	--	--	--	--	--	--
P3	<2	<2*	--	--	--	--	--	--
P6(dup)	<2	<2*	--	--	--	--	--	--
P4	<2	<2*	<0.04	(<.002)	<0.04	(<.002)	<0.04	(<.002)
P5	<2	<2*	--	--	--	--	--	--
R1	<2	<2*	<0.04	(<.002)	<0.04	(<.002)	<0.04	(<.002)
R2	--	<2*	--	--	--	--	--	--
R3	<2	<2*	--	--	--	--	--	--
R4	<2	<2	--	--	--	--	--	--
R6(dup)	--	<2	--	--	--	--	--	--
R5	--	<2	--	--	--	--	--	--
U1	<2	<2	<0.04	(<.002)	<0.04	(<.002)	<0.04	(<.002)
U2	<2	<2	--	--	--	--	--	--
U3	--	<2	--	--	--	--	--	--
U6(dup)	--	<2	--	--	--	--	--	--
U4	--	<2	--	--	--	--	--	--
U5	<2	<2	--	--	--	--	--	--
RS1	<2	<2	<0.04	(<.002)	<0.04	(<.002)	<0.04	(<.002)
RS(dup)	<2	<2	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Chromium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	51.5	--	--	--	--	--	--
A2	100	41.2	<0.1	(<0.005)	<0.1	(<0.005)	<0.1	(<0.005)
A3	170	56.7	--	--	--	--	--	--
A4	--	26.0	--	--	--	--	--	--
A5	83	34.2	--	--	--	--	--	--
A6(dup)	79	35.5	--	--	--	--	--	--
C1	160	16.0	--	--	--	--	--	--
C2	--	14.8	--	--	--	--	--	--
C3	120	12.2+	--	--	--	--	--	--
C4	150	10.1+	--	--	--	--	--	--
C5	--	11.4+	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
D1	140	32.0	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
D2	--	26.7	--	--	--	--	--	--
D3	--	25.1	--	--	--	--	--	--
D4	130	45.2	--	--	--	--	--	--
D5	340	163	--	--	--	--	--	--
F1	99	22.8	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
F2	50	25.1	--	--	--	--	--	--
F6(dup)	51	19.9	--	--	--	--	--	--
F3	--	26.6	--	--	--	--	--	--
F4	--	59.7	--	--	--	--	--	--
F5	540	313	--	--	--	--	--	--
G1	81	27.5	--	--	--	--	--	--
G2	--	17.9	--	--	--	--	--	--
G3	--	24.8	--	--	--	--	--	--
G4	59	19.5	--	--	--	--	--	--
G5	64	24.5	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
J1	--	35.9	--	--	--	--	--	--
J2	42	10.8+	--	--	--	--	--	--
J3	84	17.9	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
J4	--	18.3	--	--	--	--	--	--
J5	49	11.4+	--	--	--	--	--	--
L1	260	71.3	--	--	--	--	--	--
L2	96	36.9	--	--	--	--	--	--
L3	--	29.3	--	--	--	--	--	--
L4	78	20	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
L6(dup)	67	20.6	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
L5	--	38.4	--	--	--	--	--	--
M1	61	21.5	--	--	--	--	--	--
M2	120	37.3	--	--	--	--	--	--
M3	--	17.1	--	--	--	--	--	--
M4	57	15	<.1	(<.005)	<.1	(<.005)	<.1	(<.005)
M5	--	26.1	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Chromium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	11.8	--	--	--	--	--	--
O2	77	17.3	<0.1	(<0.005)	<0.1	(<0.005)	<0.1	(<0.005)
O3	68	15.9	--	--	--	--	--	--
O4	61	12.9	--	--	--	--	--	--
O5	--	14.7	--	--	--	--	--	--
P1	--	15.4	--	--	--	--	--	--
P2	53	12.6	--	--	--	--	--	--
P3	56	16.1	--	--	--	--	--	--
P6(dup)	54	13.4	--	--	--	--	--	--
P4	28	6.1+	<1	(<.005)	<1	(<.005)	<1	(<.005)
P5	34	7.6+	--	--	--	--	--	--
R1	55	5.0+	<1	(<.005)	<1	(<.005)	<1	(<.005)
R2	--	6.6+	--	--	--	--	--	--
R3	42	10.8	--	--	--	--	--	--
R4	68	8.8	--	--	--	--	--	--
R6(dup)	--	9.4	--	--	--	--	--	--
R5	--	9.1	--	--	--	--	--	--
U1	56	12.4	<1	(<.005)	<1	(<.005)	<1	(<.005)
U2	50	16.1	--	--	--	--	--	--
U3	--	15.7	--	--	--	--	--	--
U6(dup)	--	17.9	--	--	--	--	--	--
U4	--	12.9	--	--	--	--	--	--
U5	69	15.1	--	--	--	--	--	--
RS1	120	20.3	<1	(<.005)	<1	(<.005)	<1	(<.005)
RS(dup)	110	20.1	--	--	--	--	--	--

Table A2--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Copper							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	33.9	--	--	--	--	--	--
A2	29	22.5	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
A3	120	99.4	--	--	--	--	--	--
A4	--	23.2	--	--	--	--	--	--
A5	28	24.4	--	--	--	--	--	--
A6(dup)	32	25.4	--	--	--	--	--	--
C1	42	5.2+	--	--	--	--	--	--
C2	--	5.2+	--	--	--	--	--	--
C3	23	4.3+	--	--	--	--	--	--
C4	27	4.4+	--	--	--	--	--	--
C5	--	5.0+	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D1	13	7.2+	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D2	--	6.2+	--	--	--	--	--	--
D3	--	8.1+	--	--	--	--	--	--
D4	28	18.7	--	--	--	--	--	--
D5	68	50.9	--	--	--	--	--	--
F1	53	28.9	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
F2	30	24.9	--	--	--	--	--	--
F6(dup)	31	23.5	--	--	--	--	--	--
F3	--	18.3	--	--	--	--	--	--
F4	--	31.1	--	--	--	--	--	--
F5	29	26.5	--	--	--	--	--	--
G1	39	26.2	--	--	--	--	--	--
G2	--	15.4	--	--	--	--	--	--
G3	--	23.2	--	--	--	--	--	--
G4	49	31.7	--	--	--	--	--	--
G5	27	23.9	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J1	--	53.0	--	--	--	--	--	--
J2	30	20.2	--	--	--	--	--	--
J3	31	11.6+	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J4	--	13.4+	--	--	--	--	--	--
J5	30	11.9+	--	--	--	--	--	--
L1	53	27.3	--	--	--	--	--	--
L2	33	28.7	--	--	--	--	--	--
L3	--	14.8+	--	--	--	--	--	--
L4	28	14.7+	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L6(dup)	30	16.9+	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L5	--	16.0+	--	--	--	--	--	--
M1	28	21.6	--	--	--	--	--	--
M2	44	26.9	--	--	--	--	--	--
M3	--	25.9+	--	--	--	--	--	--
M4	28	20.0+	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
M5	--	20.7+	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Copper							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	17.8+	--	--	--	--	--	--
O2	27	19.2+	0.66	(0.033)	<0.4	(<0.02)	<0.4	(<0.02)
O3	30	18.4+	--	--	--	--	--	--
O4	29	21.5+	--	--	--	--	--	--
O5	--	20.3+	--	--	--	--	--	--
P1	--	21.9+	--	--	--	--	--	--
P2	28	16.0+	--	--	--	--	--	--
P3	27	18.9+	--	--	--	--	--	--
P6(dup)	25	16.8+	--	--	--	--	--	--
P4	22	11.1+	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
P5	23	12.9+	--	--	--	--	--	--
R1	85	9.1+	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
R2	--	13.2+	--	--	--	--	--	--
R3	26	14.6+	--	--	--	--	--	--
R4	24	12.7+	--	--	--	--	--	--
R6(dup)	--	11.7+	--	--	--	--	--	--
R5	--	13.2+	--	--	--	--	--	--
U1	26	14.6+	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
U2	37	23.5+	--	--	--	--	--	--
U3	--	17.8+	--	--	--	--	--	--
U6(dup)	--	17.1+	--	--	--	--	--	--
U4	--	14.1+	--	--	--	--	--	--
U5	24	15.0+	--	--	--	--	--	--
RS1	21	11.0+	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
RS(dup)	19	11.1+	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Iron							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	4.2	--	--	--	--	--	--
A2	5.2	3.3	0.5	(.03)	<0.4	(<0.02)	<0.4	(<0.02)
A3	8.8	6.3	--	--	--	--	--	--
A4	--	2.6	--	--	--	--	--	--
A5	4.1	3.8	--	--	--	--	--	--
A6(dup)	5.2	4.0	--	--	--	--	--	--
C1	6.1	1.3	--	--	--	--	--	--
C2	--	1.4	--	--	--	--	--	--
C3	5.9	1.1	--	--	--	--	--	--
C4	6.9	1.1	--	--	--	--	--	--
C5	--	.9	5.3	(.27)	1.9	(.10)	1.5	(.08)
D1	3.4	1.7	1.2	(.06)	1.5	(.08)	1.6	(.08)
D2	--	1.4	--	--	--	--	--	--
D3	--	1.8	--	--	--	--	--	--
D4	3.9	2.3	--	--	--	--	--	--
D5	6.0	5.0	--	--	--	--	--	--
F1	5.2	2.5	1.9	(.10)	<.4	(<.02)	1.4	(.07)
F2	3.0	2.2	--	--	--	--	--	--
F6(dup)	3.0	2.2	--	--	--	--	--	--
F3	--	2.1	--	--	--	--	--	--
F4	--	3.2	--	--	--	--	--	--
F5	4.9	3.2	--	--	--	--	--	--
G1	8.8	5.6	--	--	--	--	--	--
G2	--	3.0	--	--	--	--	--	--
G3	--	2.7	--	--	--	--	--	--
G4	5.8	3.4	--	--	--	--	--	--
G5	5.4	4.0	<.4	(<.02)	.9	(.05)	.9	(.05)
J1	--	2.8	--	--	--	--	--	--
J2	2.5	1.3	--	--	--	--	--	--
J3	4.1	1.6	.6	(.03)	.7	(.03)	1.1	(.06)
J4	--	1.2	--	--	--	--	--	--
J5	2.5	1.0	--	--	--	--	--	--
L1	5.4	2.6	--	--	--	--	--	--
L2	4.1	2.5	--	--	--	--	--	--
L3	--	2.0	--	--	--	--	--	--
L4	4.1	1.9	2.0	(.1)	.9	(.04)	.4	(.02)
L6(dup)	4.1	2.0	<.4	(<.02)	.6	(.03)	.6	(.03)
L5	--	2.3	--	--	--	--	--	--
M1	7.7	5.2	--	--	--	--	--	--
M2	7.4	4.3	--	--	--	--	--	--
M3	--	2.3	--	--	--	--	--	--
M4	4.6	3.3	<.4	(<.02)	.6	(.03)	2.0	(.10)
M5	--	2.7	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Iron							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	2.2	--	--	--	--	--	--
O2	3.8	2.1	<0.7	(<0.04)	0.7	(0.04)	0.9	(0.04)
O3	3.4	2.3	--	--	--	--	--	--
O4	5.7	2.8	--	--	--	--	--	--
O5	--	2.4	--	--	--	--	--	--
P1	--	3.0	--	--	--	--	--	--
P2	4.0	2.5	--	--	--	--	--	--
P3	4.0	2.6	--	--	--	--	--	--
P6(dup)	4.0	2.3	--	--	--	--	--	--
P4	2.8	1.1	.6	(.03)	.4	(.02)	.8	(.04)
P5	2.8	1.3	--	--	--	--	--	--
R1	9.3	2.1	6.3	(.3)	.9	(.05)	17.5	(.90)
R2	--	2.4	--	--	--	--	--	--
R3	3.8	1.7	--	--	--	--	--	--
R4	6.0	1.6	--	--	--	--	--	--
R6(dup)	--	1.7	--	--	--	--	--	--
R5	--	2.2	--	--	--	--	--	--
U1	4.6	2.3	1.2	(.06)	.6	(.03)	5.2	(.30)
U2	3.8	2.1	--	--	--	--	--	--
U3	--	2.1	--	--	--	--	--	--
U6(dup)	--	2.3	--	--	--	--	--	--
U4	--	2.0	--	--	--	--	--	--
U5	3.3	1.9	--	--	--	--	--	--
RS1	3.2	1.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
RS(dup)	3.2	1.4	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Mercury							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	0.119	--	--	--	--	--	--
A2	0.16	.093	0.003	(.0002)	<.0008	(<.00004)	<.001	(<.0001)
A3	.22	.055	--	--	--	--	--	--
A4	--	.042*	--	--	--	--	--	--
A5	.20	.061	--	--	--	--	--	--
A6(dup)	.14	.056	--	--	--	--	--	--
C1	5.9	.009*	--	--	--	--	--	--
C2	--	.01*	--	--	--	--	--	--
C3	6	.011*	--	--	--	--	--	--
C4	.20	.011*	--	--	--	--	--	--
C5	--	.009*	.003	(.0002)	<.0008	(<.00004)	<.001	(<.0001)
D1	.06	.021	.002	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
D2	--	.038*	--	--	--	--	--	--
D3	--	.031*	--	--	--	--	--	--
D4	.10	.045*	--	--	--	--	--	--
D5	.38	.185	--	--	--	--	--	--
F1	.26	.065	.003	(.0002)	<.0008	(<.00004)	<.001	(<.0001)
F2	.08	.03*	--	--	--	--	--	--
F6(dup)	.10	.03*	--	--	--	--	--	--
F3	--	.039*	--	--	--	--	--	--
F4	--	.047*	--	--	--	--	--	--
F5	.06	.058	--	--	--	--	--	--
G1	.06	.019*	--	--	--	--	--	--
G2	--	.018*	--	--	--	--	--	--
G3	--	.025*	--	--	--	--	--	--
G4	.08	.042*	--	--	--	--	--	--
G5	.06	.05*	.003	(.0002)	<.0008	(<.00004)	<.001	(<.0001)
J1	--	.025*	--	--	--	--	--	--
J2	.06	.01*	--	--	--	--	--	--
J3	.04	<.004	.003	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
J4	--	.007*	--	--	--	--	--	--
J5	.04	.013*	--	--	--	--	--	--
L1	.04	.005*	--	--	--	--	--	--
L2	.04	.015*	--	--	--	--	--	--
L3	--	.01*	--	--	--	--	--	--
L4	.04	.013*	.004	(.0002)	<.0008	(<.00004)	<.001	(<.0001)
L6(dup)	.06	.007*	.001	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
L5	--	.004*	--	--	--	--	--	--
M1	.08	.01*	--	--	--	--	--	--
M2	.08	.01*	--	--	--	--	--	--
M3	--	.05	--	--	--	--	--	--
M4	.06	.01*	.003	(.0001)	<.0008	(<.00004)	.001	(.0001)
M5	--	.05	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Mercury							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	0.006*	--	--	--	--	--	--
O2	0.04	.019*	0.004	(0.0002)	<0.0008	(<0.00004)	<0.001	(<0.0001)
O3	.06	.031*	--	--	--	--	--	--
O4	.06	.037*	--	--	--	--	--	--
O5	--	.061	--	--	--	--	--	--
P1	--	.021	--	--	--	--	--	--
P2	.04	.008*	--	--	--	--	--	--
P3	.04	<.004	--	--	--	--	--	--
P6(dup)	.04	.006*	--	--	--	--	--	--
P4	.04	.011*	.002	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
P5	.04	<.004	--	--	--	--	--	--
R1	.68	<.004	.002	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
R2	--	<.004	--	--	--	--	--	--
R3	.04	<.004	--	--	--	--	--	--
R4	.04	<.004	--	--	--	--	--	--
R6(dup)	--	<.004	--	--	--	--	--	--
R5	--	.01*	--	--	--	--	--	--
U1	.10	.006*	.002	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
U2	.08	.012*	--	--	--	--	--	--
U3	--	<.004	--	--	--	--	--	--
U6(dup)	--	.021*	--	--	--	--	--	--
U4	--	.007*	--	--	--	--	--	--
U5	.04	.006*	--	--	--	--	--	--
RS1	.12	.062	.002	(.0001)	<.0008	(<.00004)	<.001	(<.0001)
RS(dup)	.12	.04*	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Manganese							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	537	--	--	--	--	--	--
A2	410	303	0.7	(0.04)	0.9	(0.04)	3.5	(0.18)
A3	1,500	930	--	--	--	--	--	--
A4	--	277	--	--	--	--	--	--
A5	680	633	--	--	--	--	--	--
A6(dup)	650	698	--	--	--	--	--	--
C1	1,300	159	--	--	--	--	--	--
C2	--	149	--	--	--	--	--	--
C3	820	107	--	--	--	--	--	--
C4	800	112	--	--	--	--	--	--
C5	--	78	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D1	550	229	<.4	(<.02)	<.4	(<.02)	1.4	(.07)
D2	--	197	--	--	--	--	--	--
D3	--	231	--	--	--	--	--	--
D4	580	366	--	--	--	--	--	--
D5	690	631	--	--	--	--	--	--
F1	740	339	<.4	(<.02)	<.4	(<.02)	1.2	(.06)
F2	1,400	783	--	--	--	--	--	--
F6(dup)	1,400	696	--	--	--	--	--	--
F3	--	344	--	--	--	--	--	--
F4	--	757	--	--	--	--	--	--
F5	750	478	--	--	--	--	--	--
G1	1,100	825	--	--	--	--	--	--
G2	--	478	--	--	--	--	--	--
G3	--	494	--	--	--	--	--	--
G4	970	686	--	--	--	--	--	--
G5	620	644	<.4	(<.02)	<.4	(<.02)	3.6	(.18)
J1	--	571	--	--	--	--	--	--
J2	630	345	--	--	--	--	--	--
J3	780	256	<.4	(<.02)	<.4	(<.02)	.7	(.04)
J4	--	234	--	--	--	--	--	--
J5	670	233	--	--	--	--	--	--
L1	910	363	--	--	--	--	--	--
L2	720	430	--	--	--	--	--	--
L3	--	294	--	--	--	--	--	--
L4	670	340	<.4	(<.02)	<.4	(<.02)	.6	(.03)
L6(dup)	680	359	<.4	(<.02)	<.4	(<.02)	.6	(.03)
L5	--	372	--	--	--	--	--	--
M1	750	485	-	-	-	-	-	-
M2	1,000	680	-	-	-	-	-	-
M3	-	453	-	-	-	-	-	-
M4	790	814	<.4	(<.02)	.7	(.03)	6.5	(.33)
M5	-	486	-	-	-	-	-	-

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Manganese							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	389	--	--	--	--	--	--
O2	640	361	<0.4	(<0.02)	4.4	(0.2)	3.1	(0.15)
O3	600	465	--	--	--	--	--	--
O4	860	480	--	--	--	--	--	--
O5	--	361	--	--	--	--	--	--
P1	--	652	--	--	--	--	--	--
P2	690	516	--	--	--	--	--	--
P3	670	523	--	--	--	--	--	--
P6(dup)	670	499	--	--	--	--	--	--
P4	560	252	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
P5	550	279	--	--	--	--	--	--
R1	1,600	245	<.4	(<.02)	<.4	(<.02)	1.3	(.06)
R2	--	378	--	--	--	--	--	--
R3	550	325	--	--	--	--	--	--
R4	940	268	--	--	--	--	--	--
R6(dup)	--	265	--	--	--	--	--	--
R5	--	377	--	--	--	--	--	--
U1	560	390	<.4	(<.02)	<.4	(<.02)	.8	(.04)
U2	640	428	--	--	--	--	--	--
U3	--	450	--	--	--	--	--	--
U6(dup)	--	450	--	--	--	--	--	--
U4	--	371	--	--	--	--	--	--
U5	540	344	--	--	--	--	--	--
RS1	560	210	<.4	(<.02)	<.4	(<.02)	.6	(.03)
RS(dup)	570	260	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Nickel							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	26.8	--	--	--	--	--	--
A2	33	19.6	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
A3	76	63.2	--	--	--	--	--	--
A4	--	11.9	--	--	--	--	--	--
A5	24	14.2	--	--	--	--	--	--
A6(dup)	29	15.6	--	--	--	--	--	--
C1	62	10.3	--	--	--	--	--	--
C2	--	10.0	--	--	--	--	--	--
C3	55	9.0	--	--	--	--	--	--
C4	34	8.7	--	--	--	--	--	--
C5	--	7.6	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D1	66	22.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D2	--	31.3	--	--	--	--	--	--
D3	--	19.1	--	--	--	--	--	--
D4	73	39.8	--	--	--	--	--	--
D5	120	91.1	--	--	--	--	--	--
F1	49	25.6	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
F2	23	31.5	--	--	--	--	--	--
F6(dup)	21	20.1	--	--	--	--	--	--
F3	--	23.1	--	--	--	--	--	--
F4	--	56.2	--	--	--	--	--	--
F5	470	358	--	--	--	--	--	--
G1	27	20.4	--	--	--	--	--	--
G2	--	19.4	--	--	--	--	--	--
G3	--	20.6	--	--	--	--	--	--
G4	22	13.3	--	--	--	--	--	--
G5	23	17.5	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J1	--	24.6	--	--	--	--	--	--
J2	12	7.8	--	--	--	--	--	--
J3	30	12.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J4	--	17.0	--	--	--	--	--	--
J5	20	9.5	--	--	--	--	--	--
L1	70	34.1	--	--	--	--	--	--
L2	36	20.8	--	--	--	--	--	--
L3	--	16.7	--	--	--	--	--	--
L4	30	12.2	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L6(dup)	32	14.9	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L5	--	19.4	--	--	--	--	--	--
M1	15	9.7	--	--	--	--	--	--
M2	48	29.9	--	--	--	--	--	--
M3	--	26.6	--	--	--	--	--	--
M4	20	11.8	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
M5	--	27.6	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Nickel							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	12.8	--	--	--	--	--	--
O2	28	16.5	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
O3	28	17.0	--	--	--	--	--	--
O4	27	18.9	--	--	--	--	--	--
O5	--	15.7	--	--	--	--	--	--
P1	--	16.5	--	--	--	--	--	--
P2	18	10.7	--	--	--	--	--	--
P3	16	14.0	--	--	--	--	--	--
P6(dup)	16	11.3	--	--	--	--	--	--
P4	11	7.7	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
P5	11	7.1	--	--	--	--	--	--
R1	32	6.4	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
R2	--	9.2	--	--	--	--	--	--
R3	18	11.2	--	--	--	--	--	--
R4	24	9.7	--	--	--	--	--	--
R6(dup)	--	9.9	--	--	--	--	--	--
R5	--	11.7	--	--	--	--	--	--
U1	20	10.3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
U2	24	14.6	--	--	--	--	--	--
U3	--	13.9	--	--	--	--	--	--
U6(dup)	--	14.2	--	--	--	--	--	--
U4	--	10.5	--	--	--	--	--	--
U5	21	11.2	--	--	--	--	--	--
RS1	45	22.4	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
RS(dup)	44	23.7	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Lead							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	12	--	--	--	--	--	--
A2	13	9.7*	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
A3	4	4.0*	--	--	--	--	--	--
A4	--	4.0*	--	--	--	--	--	--
A5	10	10 *	--	--	--	--	--	--
A6(dup)	11	10 *	--	--	--	--	--	--
C1	12	3.2*	--	--	--	--	--	--
C2	--	2.3*	--	--	--	--	--	--
C3	15	2.1*	--	--	--	--	--	--
C4	15	3.1*	--	--	--	--	--	--
C5	--	2.3*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D1	11	5.2*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D2	--	6.1*	--	--	--	--	--	--
D3	--	3.8*	--	--	--	--	--	--
D4	9	4.7*	--	--	--	--	--	--
D5	7	12.0	--	--	--	--	--	--
F1	14	10 *	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
F2	8	5.4*	--	--	--	--	--	--
F6(dup)	8	7.4*	--	--	--	--	--	--
F3	--	6.0*	--	--	--	--	--	--
F4	--	7.3*	--	--	--	--	--	--
F5	5	3.6*	--	--	--	--	--	--
G1	12	9.9*	--	--	--	--	--	--
G2	--	5.0*	--	--	--	--	--	--
G3	--	8.6*	--	--	--	--	--	--
G4	14	8.7*	--	--	--	--	--	--
G5	15	13	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J1	--	9.9*	--	--	--	--	--	--
J2	12	5.4*	--	--	--	--	--	--
J3	17	6.6*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J4	--	4.8*	--	--	--	--	--	--
J5	10	4.2*	--	--	--	--	--	--
L1	13	5.0*	--	--	--	--	--	--
L2	16	9.5*	--	--	--	--	--	--
L3	--	8.8*	--	--	--	--	--	--
L4	12	6.4*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L6(dup)	11	3.6*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L5	--	5.9*	--	--	--	--	--	--
M1	10	9.4*	--	--	--	--	--	--
M2	7	9.2*	--	--	--	--	--	--
M3	--	6.6*	--	--	--	--	--	--
M4	12	7.9*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
M5	--	6.8*	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Lead							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	8.2*	--	--	--	--	--	--
O2	15	8.7*	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
O3	11	8.2*	--	--	--	--	--	--
O4	14	10.9	--	--	--	--	--	--
O5	--	7.0*	--	--	--	--	--	--
P1	--	11.7	--	--	--	--	--	--
P2	11	8.0*	--	--	--	--	--	--
P3	10	10.4	--	--	--	--	--	--
P6(dup)	11	9.8*	--	--	--	--	--	--
P4	11	6.7*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
P5	10	5.8*	--	--	--	--	--	--
R1	36	4.2*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
R2	--	8.0*	--	--	--	--	--	--
R3	10	6.8*	--	--	--	--	--	--
R4	12	6.0*	--	--	--	--	--	--
R6(dup)	--	5.4*	--	--	--	--	--	--
R5	--	5.3*	--	--	--	--	--	--
U1	20	13.6	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
U2	21	12.0	--	--	--	--	--	--
U3	--	11.0	--	--	--	--	--	--
U6(dup)	--	11.9	--	--	--	--	--	--
U4	--	11.2	--	--	--	--	--	--
U5	16	10.5	--	--	--	--	--	--
RS1	8	4.7*	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
RS(dup)	7	5.5*	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Antimony							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	<3	--	--	--	--	--	--
A2	1.3	<3	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
A3	1.0	<3	--	--	--	--	--	--
A4	--	<3	--	--	--	--	--	--
A5	1.4	<3	--	--	--	--	--	--
A6(dup)	1.2	<3	--	--	--	--	--	--
C1	1.3	<3	--	--	--	--	--	--
C2	--	<3	--	--	--	--	--	--
C3	1.4	<3	--	--	--	--	--	--
C4	1.9	<3	--	--	--	--	--	--
C5	--	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D1	1.3	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
D2	--	<3	--	--	--	--	--	--
D3	--	<3	--	--	--	--	--	--
D4	1.7	<3	--	--	--	--	--	--
D5	3.8	<3	--	--	--	--	--	--
F1	1.4	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
F2	1.2	<3	--	--	--	--	--	--
F6(dup)	1.0	<3	--	--	--	--	--	--
F3	--	<3	--	--	--	--	--	--
F4	--	<3	--	--	--	--	--	--
F5	1.1	<3	--	--	--	--	--	--
G1	1.3	<3	--	--	--	--	--	--
G2	--	<3	--	--	--	--	--	--
G3	--	<3	--	--	--	--	--	--
G4	1.5	<3	--	--	--	--	--	--
G5	1.6	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J1	--	<3	--	--	--	--	--	--
J2	.7	<3	--	--	--	--	--	--
J3	1.7	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
J4	--	<3	--	--	--	--	--	--
J5	1.2	<3	--	--	--	--	--	--
L1	.6	<3	--	--	--	--	--	--
L2	1.6	<3	--	--	--	--	--	--
L3	--	<3	--	--	--	--	--	--
L4	1.0	<3	<.4	(<.02)	<.4	(<.02)	.4	(.02)
L6(dup)	1.1	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
L5	--	<3	--	--	--	--	--	--
M1	0.8	<3	-	-	-	-	-	-
M2	.8	<3	-	-	-	-	-	-
M3	-	<3	-	-	-	-	-	-
M4	.8	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
M5	-	<3	-	-	-	-	-	-

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Antimony							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	<3	--	--	--	--	--	--
O2	1.6	<3	<0.4	(<0.02)	<0.4	(<0.02)	0.4	(0.02)
O3	1.2	<3	--	--	--	--	--	--
O4	1.7	<3	--	--	--	--	--	--
O5	--	<3	--	--	--	--	--	--
P1	--	<3	--	--	--	--	--	--
P2	1.2	<3	--	--	--	--	--	--
P3	1.1	<3	--	--	--	--	--	--
P6(dup)	1.2	<3	--	--	--	--	--	--
P4	<.7	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
P5	1.0	<3	--	--	--	--	--	--
R1	3.8	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
R2	--	<3	--	--	--	--	--	--
R3	.8	<3	--	--	--	--	--	--
R4	1.5	<3	--	--	--	--	--	--
R6(dup)	--	<3	--	--	--	--	--	--
R5	--	<3	--	--	--	--	--	--
U1	1.9	<3	<.4	(<.02)	<.4	(<.02)	.4	(.02)
U2	1.3	<3	--	--	--	--	--	--
U3	--	<3	--	--	--	--	--	--
U6(dup)	--	<3	--	--	--	--	--	--
U4	--	<3	--	--	--	--	--	--
U5	1.2	<3	--	--	--	--	--	--
RS1	1.2	<3	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
RS(dup)	1.3	<3	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Selenium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	<0.5	--	--	--	--	--	--
A2	1.2	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
A3	1.2	<.5	--	--	--	--	--	--
A4	--	<.5	--	--	--	--	--	--
A5	.2	<.5	--	--	--	--	--	--
A6(dup)	.3	<.5	--	--	--	--	--	--
C1	.3	<.5	--	--	--	--	--	--
C2	--	<.5	--	--	--	--	--	--
C3	.4	<.5	--	--	--	--	--	--
C4	.3	<.5	--	--	--	--	--	--
C5	--	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
D1	.2	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
D2	--	<.5	--	--	--	--	--	--
D3	--	<.5	--	--	--	--	--	--
D4	.1	<.5	--	--	--	--	--	--
D5	.7	<.5	--	--	--	--	--	--
F1	.4	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
F2	.5	<.5	--	--	--	--	--	--
F6(dup)	.4	<.5	--	--	--	--	--	--
F3	--	<.5	--	--	--	--	--	--
F4	--	<.5	--	--	--	--	--	--
F5	.1	<.5	--	--	--	--	--	--
G1	.3	<.5	--	--	--	--	--	--
G2	--	<.5	--	--	--	--	--	--
G3	--	<.5	--	--	--	--	--	--
G4	.3	<.5	--	--	--	--	--	--
G5	.2	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
J1	--	<.5	--	--	--	--	--	--
J2	1.0	<.5	--	--	--	--	--	--
J3	.1	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
J4	--	<.5	--	--	--	--	--	--
J5	<.1	<.5	--	--	--	--	--	--
L1	.1	<.5	--	--	--	--	--	--
L2	.2	<.5	--	--	--	--	--	--
L3	--	<.5	--	--	--	--	--	--
L4	.1	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
L6(dup)	.1	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
L5	--	<.5	--	--	--	--	--	--
M1	.1	<.5	--	--	--	--	--	--
M2	.2	<.5	--	--	--	--	--	--
M3	--	<.5	--	--	--	--	--	--
M4	<.1	<.5	<1	(<.05)	<1	(<.05)	<1	(<.05)
M5	--	<.5	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Selenium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	<0.5	--	--	--	--	--	--
O2	<0.1	<.5	<1	(<0.05)	<1	(<0.05)	<1	(<0.05)
O3	.1	<.5	--	--	--	--	--	--
O4	.1	<.5	--	--	--	--	--	--
O5	--	<.5	--	--	--	--	--	--
P1	--	<.5	--	--	--	--	--	--
P2	.1	<.5	--	--	--	--	--	--
P3	.1	<.5	--	--	--	--	--	--
P6(dup)	.1	<.5	--	--	--	--	--	--
P4	<1	<.5	<1	(<0.05)	<1	(<0.05)	<1	(<0.05)
P5	<1	<.5	--	--	--	--	--	--
R1	<1	<5.4	<1	(<0.05)	<1	(<0.05)	<1	(<0.05)
R2	--	<.5	--	--	--	--	--	--
R3	<1	<.5	--	--	--	--	--	--
R4	.1	<.5	--	--	--	--	--	--
R6(dup)	--	<.5	--	--	--	--	--	--
R5	--	<.5	--	--	--	--	--	--
U1	<1	<.5	<1	(<0.05)	<1	(<0.05)	<1	(<0.05)
U2	1.0	<.5	--	--	--	--	--	--
U3	--	<.5	--	--	--	--	--	--
U6(dup)	--	<.5	--	--	--	--	--	--
U4	--	<.5	--	--	--	--	--	--
U5	<1	<.5	--	--	--	--	--	--
RS1	.3	<.5	<1	(<0.05)	<1	(<0.05)	<1	(<0.05)
RS(dup)	.3	<.5	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Thallium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	<5	--	--	--	--	--	--
A2	--	<5	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
A3	--	<5	--	--	--	--	--	--
A4	--	<5	--	--	--	--	--	--
A5	--	<5	--	--	--	--	--	--
A6(dup)	--	<7.1	--	--	--	--	--	--
C1	--	<5	--	--	--	--	--	--
C2	--	<5	--	--	--	--	--	--
C3	--	<5	--	--	--	--	--	--
C4	--	<5	--	--	--	--	--	--
C5	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
D1	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
D2	--	<5	--	--	--	--	--	--
D3	--	<5	--	--	--	--	--	--
D4	--	<5	--	--	--	--	--	--
D5	--	<5	--	--	--	--	--	--
F1	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
F2	--	<5	--	--	--	--	--	--
F6(dup)	--	<5	--	--	--	--	--	--
F3	--	<5	--	--	--	--	--	--
F4	--	<5	--	--	--	--	--	--
F5	--	>5.4*	--	--	--	--	--	--
G1	--	<5	--	--	--	--	--	--
G2	--	<5	--	--	--	--	--	--
G3	--	<5	--	--	--	--	--	--
G4	--	<5	--	--	--	--	--	--
G5	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
J1	--	>9.2*	--	--	--	--	--	--
J2	--	<5	--	--	--	--	--	--
J3	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
J4	--	<5	--	--	--	--	--	--
J5	--	<5	--	--	--	--	--	--
L1	--	>14 *	--	--	--	--	--	--
L2	--	>5.1*	--	--	--	--	--	--
L3	--	<5	--	--	--	--	--	--
L4	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
L6(dup)	--	<5	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
L5	--	>7 *	--	--	--	--	--	--
M1	--	>7.9*	--	--	--	--	--	--
M2	--	>6.2*	--	--	--	--	--	--
M3	--	>9.3*	--	--	--	--	--	--
M4	--	>6.3*	<4	(<0.02)	<4	(<0.02)	<4	(<0.02)
M5	--	>9.2*	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Thallium							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	>6.5*	--	--	--	--	--	--
O2	--	>7.6*	<0.4	(<0.02)	<0.4	(<0.02)	<0.4	(<0.02)
O3	--	>8.9*	--	--	--	--	--	--
O4	--	>6.2*	--	--	--	--	--	--
O5	--	>5	--	--	--	--	--	--
P1	--	>10 *	--	--	--	--	--	--
P2	--	<5	--	--	--	--	--	--
P3	--	>8.5*	--	--	--	--	--	--
P6(dup)	--	>6.9*	--	--	--	--	--	--
P4	--	<5	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
P5	--	>9 *	--	--	--	--	--	--
R1	--	<5	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
R2	--	>7.3*	--	--	--	--	--	--
R3	--	<5	--	--	--	--	--	--
R4	--	>5.4*	--	--	--	--	--	--
R6(dup)	--	<5	--	--	--	--	--	--
R5	--	<5	--	--	--	--	--	--
U1	--	<5	<.4	(<.02)	<.4	(<.02)	<2.0	(<.1)
U2	--	>5.8*	--	--	--	--	--	--
U3	--	<5	--	--	--	--	--	--
U6(dup)	--	<5	--	--	--	--	--	--
U4	--	>5.3*	--	--	--	--	--	--
U5	--	<5	--	--	--	--	--	--
RS1	--	<5	<.4	(<.02)	<.4	(<.02)	<.4	(<.02)
RS(dup)	--	<5.7	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Zinc							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
A1	--	63.1	--	--	--	--	--	--
A2	80	53.8	<0.4	(<0.02)	0.6	(0.03)	1.8	(0.09)
A3	100	86.0	--	--	--	--	--	--
A4	--	44.5	--	--	--	--	--	--
A5	95	63.0	--	--	--	--	--	--
A6(dup)	96	68.0	--	--	--	--	--	--
C1	280	24.4	--	--	--	--	--	--
C2	--	27.5	--	--	--	--	--	--
C3	140	21.1	--	--	--	--	--	--
C4	130	24.6	--	--	--	--	--	--
C5	--	24.1	<.4	(<.02)	.6	(.03)	1.2	(.06)
D1	110	36.7	<.4	(<.02)	1.1	(.6)	1.3	(.07)
D2	--	42.4	--	--	--	--	--	--
D3	--	45.0	--	--	--	--	--	--
D4	89	54.0	--	--	--	--	--	--
D5	130	116	--	--	--	--	--	--
F1	120	46.5	<.4	(<.02)	.5	(.2)	1.2	(.06)
F2	76	62.7	--	--	--	--	--	--
F6(dup)	77	59.5	--	--	--	--	--	--
F3	--	37.9	--	--	--	--	--	--
F4	--	90.7	--	--	--	--	--	--
F5	69	47.9	--	--	--	--	--	--
G1	130	82.1	--	--	--	--	--	--
G2	--	50.8	--	--	--	--	--	--
G3	--	63.0	--	--	--	--	--	--
G4	120	75.3	--	--	--	--	--	--
G5	94	74.0	<.4	(<.02)	.6	(.03)	1.3	(.06)
J1	--	77.9*	--	--	--	--	--	--
J2	67	39.4	--	--	--	--	--	--
J3	93	39.6	.4	(.02)	.9	(.5)	2.0	(.10)
J4	--	31.4*+	--	--	--	--	--	--
J5	65	30.7+	--	--	--	--	--	--
L1	160	82.3*	--	--	--	--	--	--
L2	110	75.4*	--	--	--	--	--	--
L3	--	58.3*	--	--	--	--	--	--
L4	82	41.0	<.4	(<.02)	.4	(.02)	1.8	(.09)
L6(dup)	82	46.9	.4	(.02)	<.4	(<.02)	1.5	(.08)
L5	--	56.4*	--	--	--	--	--	--
M1	97	70.5*	--	--	--	--	--	--
M2	110	80.7*	--	--	--	--	--	--
M3	--	37.0*	--	--	--	--	--	--
M4	81	45.2*	<.4	(<.02)	1.0	(.05)	1.8	(.09)
M5	--	38.8*	--	--	--	--	--	--

Table A2.--Concentrations of metals in soils in Washington determined by different laboratory methods--Continued

Sample number	Zinc							
	Total	Total recoverable	ASTM		EP-TOX		TCLP	
O1	--	41.5*	--	--	--	--	--	--
O2	70	40.5*	0.6	(0.03)	0.4	(0.02)	0.7	(0.03)
O3	76	40.5*	--	--	--	--	--	--
O4	88	47.4*	--	--	--	--	--	--
O5	--	42.4*	--	--	--	--	--	--
P1	--	49.4*	--	--	--	--	--	--
P2	73	43.8*	--	--	--	--	--	--
P3	72	47.1*	--	--	--	--	--	--
P6(dup)	69	44.1*	--	--	--	--	--	--
P4	63	26.3*	.5	(.03)	.7	(.4)	1.5	(.08)
P5	61	31.5*	--	--	--	--	--	--
R1	180	37.4*	<.4	(<.02)	.5	(.3)	2.1	(.11)
R2	--	42.2*	--	--	--	--	--	--
R3	66	32.4*	--	--	--	--	--	--
R4	84	30.3*	--	--	--	--	--	--
R6(dup)	--	31.6*	--	--	--	--	--	--
R5	--	39.7*	--	--	--	--	--	--
U1	96	49.6*	.8	(.04)	<.4	(<.02)	1.9	(.10)
U2	86	46.8*	--	--	--	--	--	--
U3	--	48.2*	--	--	--	--	--	--
U6(dup)	--	51.6*	--	--	--	--	--	--
U4	--	44.6*	--	--	--	--	--	--
U5	70	42.9*	--	--	--	--	--	--
RS1	53	23.7*	<.4	(<.02)	.4	(.02)	1.2	(.06)
RS(dup)	54	25.4*	--	--	--	--	--	--

Table A3.--Particle-size distribution of soil samples in Washington

[(dup), indicates duplicate of preceding sample; all samples were sieved prior to determination of distribution to remove particles greater than 19 millimeters]

Sample number	Percent of particles finer than indicated size, in millimeters								
	16.0	8.0	4.0	2.0	1.0	0.5	0.25	0.125	0.063
A1	100.0	85.9	68.4	57.7	41.3	28.4	17.8	9.8	4.1
A2	89.1	73.2	58.4	48.5	33.3	22.5	15.0	8.6	3.0
A3	97.4	91.8	82.1	80.2	72.7	61.6	46.3	26.5	11.5
A4	99.0	85.7	69.1	55.7	40.8	31.0	22.9	13.1	5.8
A5	100.0	95.9	74.2	59.7	42.7	27.3	15.6	8.8	4.2
A6(dup)	100.0	100.0	89.2	71.8	52.0	35.8	23.6	15.9	8.7
C1	100.0	100.0	100.0	100.0	100.0	98.9	59.0	2.3	.1
C2	100.0	100.0	100.0	100.0	99.9	99.9	97.4	6.3	.2
C3	100.0	100.0	100.0	100.0	100.0	99.9	96.1	3.9	.4
C4	100.0	100.0	100.0	100.0	99.9	99.9	89.4	3.9	.7
C5	100.0	100.0	100.0	100.0	99.9	99.8	97.3	4.8	1.5
D1	98.5	82.1	72.0	67.5	61.6	50.3	30.1	18.7	11.1
D2	97.6	78.5	65.8	59.7	55.3	47.8	28.5	19.0	12.7
D3	100.0	89.4	79.6	76.2	71.0	61.5	38.2	23.1	14.6
D4	98.4	87.1	74.3	68.2	60.8	52.2	37.3	23.9	13.2
D5	98.2	83.5	67.5	56.9	42.4	30.8	20.6	12.2	5.8
F1	84.4	44.7	26.3	20.7	16.9	14.7	11.9	6.6	2.7
F2	93.1	66.2	51.1	43.0	36.8	29.9	22.2	15.7	10.0
F6(dup)	91.2	62.9	49.3	40.9	34.9	28.3	21.1	15.0	9.6
F3	97.7	90.9	84.1	80.5	75.1	67.0	50.1	33.7	20.1
F4	100.0	99.0	91.4	77.3	58.0	40.8	26.4	17.5	11.9
F5	100.0	97.2	87.4	80.2	67.4	56.3	43.9	30.1	16.7
G1	100.0	98.3	95.5	93.0	81.6	63.8	44.5	24.7	10.5
G2	100.0	99.5	99.2	98.0	92.9	76.5	39.0	20.8	10.8
G3	98.2	83.9	70.6	60.8	48.4	39.2	32.8	23.8	8.8
G4	100.0	89.1	75.0	64.1	48.8	36.6	24.7	16.0	9.2
G5	100.0	100.0	100.0	87.5	65.9	50.5	40.3	33.3	23.0
J1	100.0	100.0	100.0	100.0	96.8	77.5	57.2	40.8	27.5
J2	100.0	100.0	100.0	100.0	96.5	91.5	85.9	76.3	53.3
J3	100.0	95.2	91.1	89.4	85.5	76.8	61.0	31.8	10.2
J4	100.0	99.0	98.6	98.0	96.0	89.0	76.0	56.1	27.8
J5	100.0	94.5	90.5	87.4	81.7	73.4	62.7	49.0	30.5
L1	100.0	100.0	100.0	100.0	81.3	60.6	44.5	28.2	16.5
L2	100.0	98.7	91.9	81.8	63.1	44.9	30.7	19.7	11.1
L3	100.0	95.7	89.4	82.6	67.3	47.3	29.4	18.0	9.1
L4	100.0	100.0	99.7	98.5	92.0	77.3	54.4	33.9	20.5
L6(dup)	100.0	100.0	100.0	98.7	93.0	79.4	54.9	34.1	20.7
L5	97.8	93.4	86.0	80.4	67.4	51.5	36.7	22.4	10.6

Table A3.--Particle-size distribution of soil samples in Washington--Continued

Sample number	Percent of particles finer than indicated size, in millimeters								
	16.0	8.0	4.0	2.0	1.0	0.5	0.25	0.125	0.063
M1	95.6	74.3	58.1	48.1	37.9	30.2	21.6	13.1	6.3
M2	96.9	81.3	65.6	58.3	42.2	24.4	11.1	5.2	2.6
M3	98.9	92.7	85.8	82.4	76.4	70.6	61.8	49.9	31.7
M4	97.2	83.0	68.2	56.3	42.0	33.3	24.5	14.1	7.4
M5	96.3	83.7	67.5	59.4	49.8	39.3	27.6	18.0	9.5
O1	100.0	100.0	100.0	99.8	99.6	99.4	98.7	93.5	54.4
O2	100.0	100.0	100.0	100.0	99.7	98.9	96.8	90.9	70.5
O3	100.0	96.9	92.7	87.0	78.7	70.2	57.0	44.6	32.2
O4	100.0	100.0	99.7	95.6	90.5	85.1	79.4	74.1	62.1
O5	95.4	79.6	68.9	59.9	48.0	30.8	16.3	8.6	3.9
P1	100.0	98.5	97.5	94.9	88.9	80.3	67.1	50.5	27.4
P2	100.0	99.2	97.1	95.8	91.9	88.2	83.6	75.7	55.9
P3	100.0	100.0	100.0	98.1	94.0	88.7	81.1	72.6	52.4
P6(dup)	100.0	100.0	100.0	99.9	97.7	92.0	83.2	74.0	53.0
P4	100.0	100.0	100.0	99.9	99.7	99.5	97.6	86.4	55.6
P5	100.0	100.0	100.0	100.0	99.9	99.8	98.4	89.1	64.2
R1	100.0	100.0	100.0	100.0	99.9	97.6	76.5	21.6	.7
R2	100.0	100.0	99.9	99.8	99.7	99.3	96.5	61.8	11.0
R3	100.0	100.0	100.0	99.8	99.1	97.3	94.9	89.8	70.9
R4	100.0	95.7	94.2	93.7	93.3	92.7	87.9	68.0	23.3
R6(dup)	98.7	94.7	93.1	92.6	92.2	91.6	87.1	67.1	22.5
R5	100.0	100.0	100.0	99.8	99.2	97.1	82.6	39.7	13.8
U1	96.7	83.9	75.4	67.7	49.8	33.4	18.4	8.2	3.5
U2	98.2	73.3	48.4	29.0	16.4	10.9	8.5	6.9	5.1
U3	100.0	90.3	84.5	82.2	78.4	68.7	53.5	41.4	28.3
U6(dup)	99.2	88.6	81.1	78.1	73.0	62.9	49.3	38.2	25.7
U4	100.0	98.5	96.7	94.5	91.9	58.2	13.7	9.1	5.6
U5	100.0	93.6	85.7	76.2	61.0	44.5	29.9	21.3	12.1
RS1	100.0	100.0	100.0	100.0	94.3	81.4	55.2	31.5	15.1

Table A4.--Miscellaneous characteristics of soil samples in Washington

[Concentrations of carbon are in percent of dry soil; concentrations of TPH (Total Petroleum Hydrocarbons) and PCB's (Polychlorinated Biphenyls) are in milligrams per kilogram of dry soil; 1:1, pH values determined using 1:1 mixture by weight of soil and deionized water; CaCl₂, pH values determined after the addition of CaCl₂ to the soil-water mixture; --, no data; (dup), indicates duplicate of preceding sample]

Sample number	Carbon		pH		TPH	PCB's
	Organic	Inorganic	1:1	CaCl ₂		
A1	--	--	5.4	4.5	<40	<27
A2	1.9	0.02	5.1	4.2	<40	<21
A3	4.6	.04	5.7	4.7	<40	<22*
A4	--	--	5.3	4.2	<40	<19
A5	.6	<.01	5.7	4.6	<40	<19
A6(dup)	.6	<.01	5.6	4.5	<40	<19
C1	3.6	<.01	7.5	6.0	<40	<10
C2	--	--	6.7	5.8	<40	<10
C3	1.0	<.01	6.4	5.2	<40	<10
C4	3.9	.03	7.0	5.8	<40	<10
C5	--	--	5.3	4.2	<40	<20
D1	2.6	.03	4.8	4.4	<40	<17
D2	--	--	5.9	4.9	<40	<17
D3	--	--	5.3	4.3	<40	<17
D4	1.4	<.01	5.0	4.3	<40	<18
D5	3.0	.03	5.2	4.5	<40	<22
F1	3.1	.04	5.8	5.0	<40	<12
F2	11.9	.02	6.0	4.9	<40	<10
F6(dup)	12.2	.01	5.9	5.0	<40	<10
F3	--	--	5.5	4.5	<40	<10
F4	--	--	6.6	5.2	<40	<18
F5	.4	<.01	6.3	5.0	<40	<17
G1	.9	<.01	6.0	5.1	<40	<17
G2	--	--	5.9	5.0	<40	<17
G3	--	--	6.0	5.3	<40	<18
G4	1.8	<.01	6.0	4.7	<40	<18
G5	.7	<.01	5.2	4.4	<40	<18
J1	--	--	7.9	7.3	<40	<21
J2	1.6	<.01	7.3	6.2	<43	<18
J3	.7	<.01	7.3	6.5	<40	<16
J4	--	--	8.0	6.6	<40	<16
J5	1.5	<.01	6.8	5.7	<40	<16

Table A4.--Miscellaneous characteristics of soil samples in Washington --Continued

Sample number	Carbon		pH		TPH	PCB's
	Organic	Inorganic	1:1	CaCl ₂		
L1	1.7	<.01	6.8	5.5	<40	<20*
L2	3.1	<.01	7.5	6.6	<40	<22
L3	--	--	6.1	5.3	<40	<22
L4	.8	<.01	6.9	6.2	<40	<19*
L6(dup)	.8	<.01	6.9	6.2	<40	<22
L5	--	--	7.6	7.4	<40	<21*
M1	1.8	<0.01	7.3	6.5	<40	<18*
M2	2.2	<.01	7.0	7.0	<40	<20*
M3	--	--	8.6	8.2	<40	<16*
M4	1.3	<.01	6.7	6.1	<40	<17*
M5	--	--	7.0	5.9	<40	<18
O1	--	--	8.2	7.4	<40	<17*
O2	.4	1.1	8.9	7.6	<40	<17*
O3	.8	.5	8.4	7.6	<40	<17*
O4	.5	.4	8.4	7.7	<40	<17
O5	--	--	7.7	6.7	<40	<16
P1	--	--	7.8	7.2	<40	<19
P2	2.3	<.01	7.3	6.4	<40	<17
P3	1.4	<.01	6.8	5.9	<40	<17
P6(dup)	1.6	<.01	6.7	5.9	<40	<17
P4	--	--	6.8	5.9	<40	<19
P5	1.7	<.01	7.0	6.0	<40	<17
R1	2.9	.01	7.5	6.6	<40	<16
R2	--	--	8.5	8.1	<40	<19
R3	.4	<.01	7.9	7.0	<40	<17
R4	.8	.2	8.1	8.1	<40	<16
R6(dup)	--	--	8.4	7.9	<40	<16
R5	--	--	8.7	7.7	<40	<16
U1	.5	<.01	6.4	5.6	<40	<17*
U2	.6	<.01	6.5	5.6	<40	<16*
U3	--	--	6.9	6.3	<40	<17*
U6(dup)	--	--	6.9	5.6	<40	<17*
U4	--	--	7.8	6.5	<40	<16*
U5	.5	<.01	7.2	6.1	<40	<16
RS1	1.5	.02	5.5	5.0	--	--
RS(dup)	1.5	.01	5.5	5.1	--	--

* Estimated; holding time prior to laboratory determinations exceeded.